“NEW” COMPRESSED AIR PATENTS (new to this collection)

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M. ADENOT.

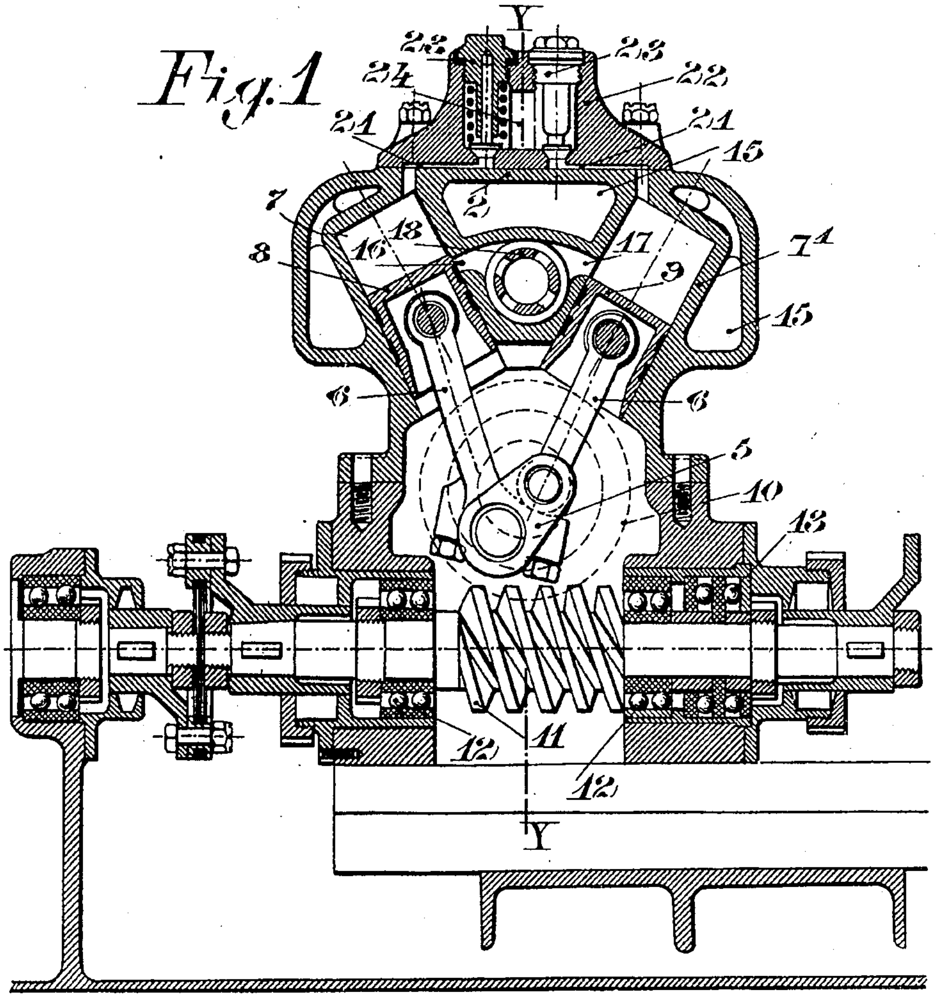
COMPRESSED AIR MECHANISM FOR MOTOR CARS AND THE LIKE.

APPLICATION FILED MAY 2, 1921.

1,398,355. Patented Nov. 29, 1921.

2 SHEETS—SHEET 1.

Fig. 1



Witnesses

Jean Germain

Guillaume Pioche

Inventor

Marius Adenot

M. ADENOT.

COMPRESSED AIR MECHANISM FOR MOTOR CARS AND THE LIKE.

APPLICATION FILED MAY 2, 1921.

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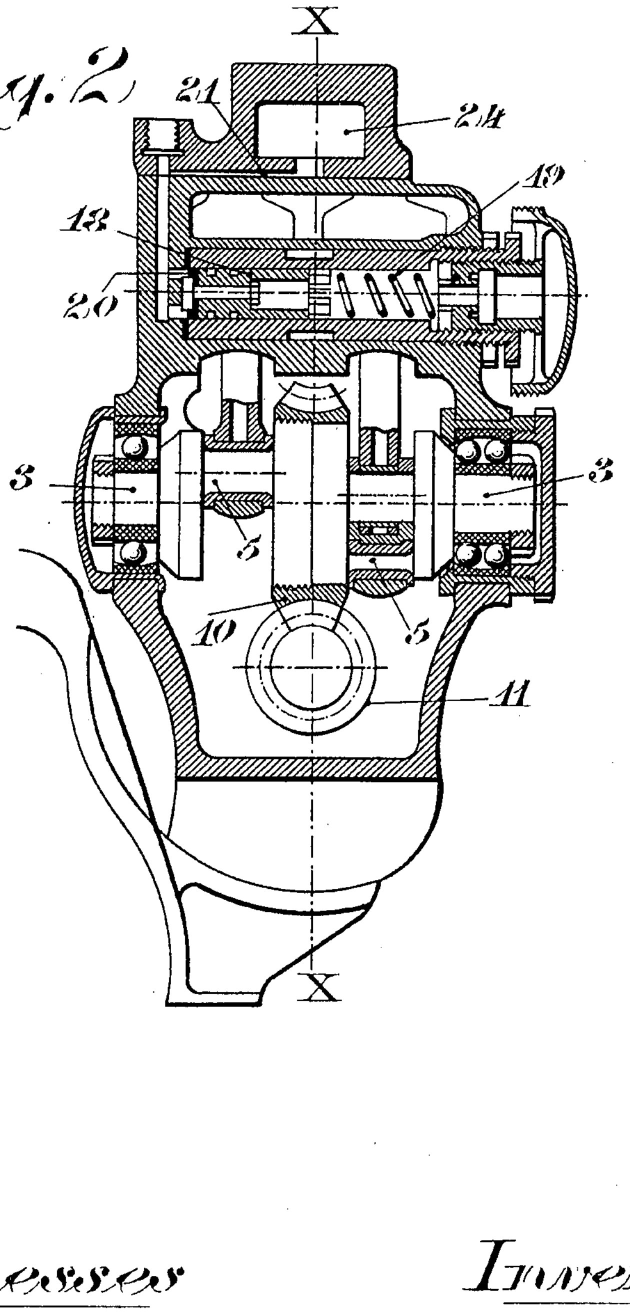
2 SHEETS—SHEET 2.

Fig. 2



Witnesses

Jean Germain
Guillaume Bioche

Inventor

Marius Adenot

UNITED STATES PATENT OFFICE.

MARIUS ADENOT, OF CALUIRE, FRANCE, ASSIGNOR TO SOCIÉTÉ LYONNAISE D'INDUSTRIE MECANIQUE, A SOCIETE ANONYME OF FRANCE.

COMPRESSED-AIR MECHANISM FOR MOTOR-CARS AND THE LIKE.

1,398,355. Specification of Letters Patent. Patented Nov. 29, 1921.

Application filed May 2, 1921. Serial No. 466,144.

To all whom it may concern:

Be it known that I, Marius Adenot, citizen of the French Republic, of 5 Chemin du Vallon, Caluire, Rhone, France, have invented certain new and useful Compressed-Air Mechanism for Motor-Cars and the like, (for which I have filed an application in France on March 10, 1920), of which the following is a specification.

This invention relates to compressed air mechanism for motor cars and the like.

In the improved mechanism the air compressing cylinders are of equal size and are inclined to one another, the pistons of the cylinders being actuated by a crank shaft driven by means of a worm wheel and a worm connected to the motor shaft of the car by means of an elastic joint; the said cylinders communicate with a chamber in which is a movable piston submitted to the action of a spring and operating to obturate the air admission ports to the cylinders when the air pressure reaches a certain value.

The annexed drawings illustrate the invention.

Figure 1 is a longitudinal vertical section of the apparatus taken on line X—X of Fig. 2.

Fig. 2 is a cross section on line Y—Y of Fig. 1.

The apparatus is composed of a compressor body 2 having inclined cylinders 7, 7^1. The rods 6 of the pistons 8 and 9 are coupled to two cranks 5 keyed at 180° to one another on the shaft 3.

The movement of the motor of the car is transmitted to the shaft 3 through a worm wheel 10 arranged between the two connecting rods 6, which gears with a worm 11 mounted on ball bearings 12, 13 and directly driven by the motor of the car through an elastic joint 14. The cylinders 7, 7^1 are surrounded by a water circulation jacket 15.

The admission of the air into the cylinders 7, 7^1 is effected through ports 16, 17 uncovered when the pistons 8 and 9 approach their low dead point. These ports may be closed by a piston 18 which moves while compressing a spring 19 under the effect of the compressed air acting on its rear surface 20.

When the pressure of the compressed air reaches the fixed limit (which is determined by the compression of the spring 19) the piston 18 obturates the ports 16, 17, and the admission ceases and is resumed as soon as the pressure has decreased in the piping. At this instant the spring 19 pushes back the piston 18 which again uncovers the ports 16, 17.

The exhaust of the compressed air is effected through the conduits 21 provided in the casing and in a valve box 22. Four exhaust valves such as 23 communicate through a common chamber 24 with the outlet pipe for the compressed air.

The compressor above described is arranged so that it can be adapted to any motor, single or tandem with the magneto, the lighting dynamo or any other accessory member. It could be comprised in the same casting with the block of the cylinders of the car motor, instead of being an independent member as in the example illustrated.

What I claim as my invention and desire to secure by Letters Patent of the United States is:—

Air compressing mechanism for motor cars and the like comprising inclined air compressing cylinders, pistons in said cylinders, connecting rods connecting said pistons to said crank shaft, a worm wheel on said crank-shaft, a worm gearing with said worm wheel, an elastic joint coupling said worm to the motor shaft, a chamber in communication with said cylinders, a piston valve movable in said chamber, a spring acting on said piston valve which obturates the air admission ports of said cylinders when the pressure of the compressed air attains a determined value and valves regulating the delivery of the compressed air.

In witness whereof I have signed this specification in the presence of two witnesses.

MARIUS ADENOT.

Witnesses:
Julian Cemble Friedburg,
Jean Germain.

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US005515675A

United States Patent [19]

Bindschatel

[11] **Patent Number: 5,515,675**

[45] **Date of Patent: May 14, 1996**

[54] **APPARATUS TO CONVERT A FOUR-STROKE INTERNAL COMBUSTION ENGINE TO A TWO-STROKE PNEUMATICALLY POWERED ENGINE**

[76] Inventor: **Lyle D. Bindschatel**, 7617 Wood Rd., Corryton, Tenn. 37721

[21] Appl. No.: **425,790**

[22] Filed: **Apr. 20, 1995**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 344,162, Nov. 23, 1994, abandoned.

[51] **Int. Cl.**^{6} **F16D 31/02**

[52] **U.S. Cl.** **60/370**; 60/407

[58] **Field of Search** 60/370, 371, 325, 60/407, 408, 415, 416; 180/68.3, 271, 287

[56] **References Cited**

U.S. PATENT DOCUMENTS

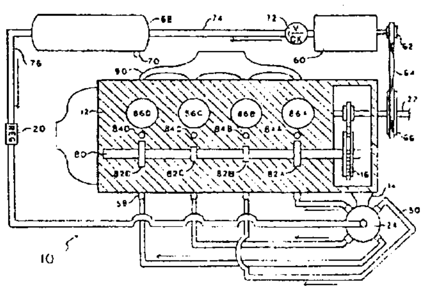
3,547,042	12/1970	O'Connor	104/155
3,704,760	12/1972	Maruyama	180/66 B
3,765,180	10/1973	Brown	60/370
3,885,387	5/1975	Simington	60/370
3,925,984	12/1975	Holleyman	60/370
3,980,152	9/1976	Manor	180/66 B
4,018,050	4/1977	Murphy	60/370
4,102,130	7/1978	Sticklin	60/407
4,162,614	7/1979	Holleyman	60/370
4,292,804	10/1981	Rogers, Sr.	60/407
4,311,917	1/1982	Hencey, Jr. et al.	290/1 A
4,337,842	7/1982	Spangler et al.	180/302
4,355,508	10/1982	Blenke et al.	60/416
4,370,857	2/1983	Miller	60/413
4,383,589	5/1983	Fox	180/165
4,478,304	10/1984	Delano	180/165
4,507,918	4/1985	Holleyman	60/370
4,596,119	6/1986	Johnson	60/407
4,616,476	10/1986	Oneyama et al.	60/414
4,651,525	3/1987	Cestero	60/416
4,769,988	9/1988	Clark	60/371 X
4,774,891	10/1988	Coester	104/130
4,896,505	10/1990	Holleyman	60/370
5,115,145	5/1992	Westberg	307/10.3
5,163,292	11/1992	Holleyman	60/370
5,326,229	7/1994	Collins	417/201
5,375,417	12/1994	Barth	60/370

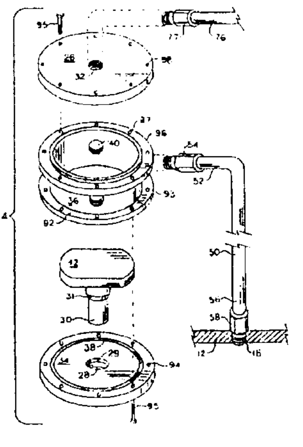
Primary Examiner—Hoang Nguyen

[57] **ABSTRACT**

An apparatus (**10**) to convert a four-stroke internal combustion engine to a two-stroke pneumatically powered engine. An air compressor (**60**) is driven using the rotation of the crankshaft (**22**) and compressed air is delivered through a supply line (**74**) to at least one holding tank (**68**). A supply line (**76**) delivers compressed air from the tank (**68**) through a regulator (**20**), which controls the pressure and volume, to the pneumatic distributor (**24**). A plurality of high pressure hoses (**50**) finally communicates the compressed air to the cylinders (**86**) of the engine (**12**) via the spark plug orifices (**18**). The pneumatic distributor (**24**) has a rotor (**42**) which opens gate valves (**44**) to supply compressed air to the cylinders (**86**) wherein the pistons (**88**) are at top dead center, making every downstroke a power stroke. The modified dual-lobed camshaft (**80**) operates the exhaust valves (**84**) so that every upstroke of a piston (**88**) is an exhaust stroke and exhaust freely escapes through the exhaust manifold (**90**).

2 Claims, 3 Drawing Sheets





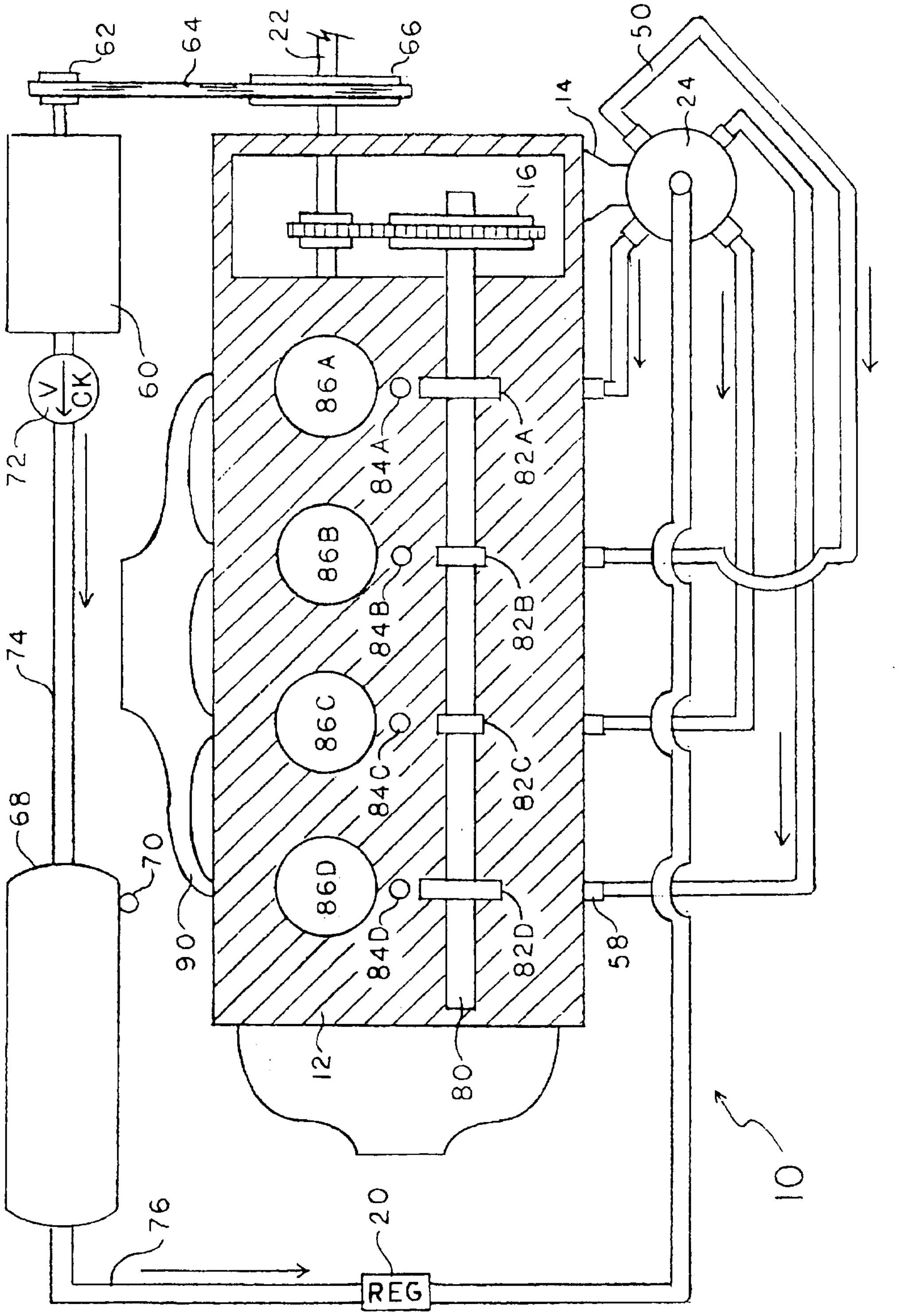

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FIG. 1

FIG. 2

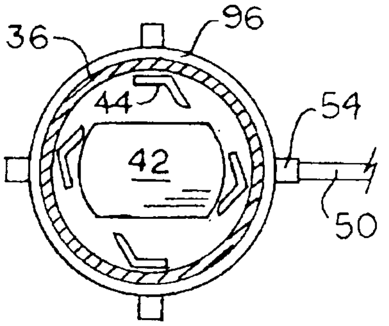


FIG. 3

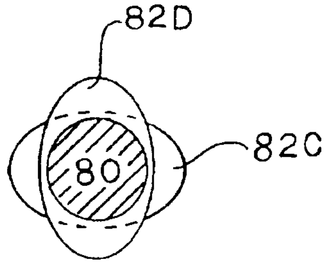


FIG. 4

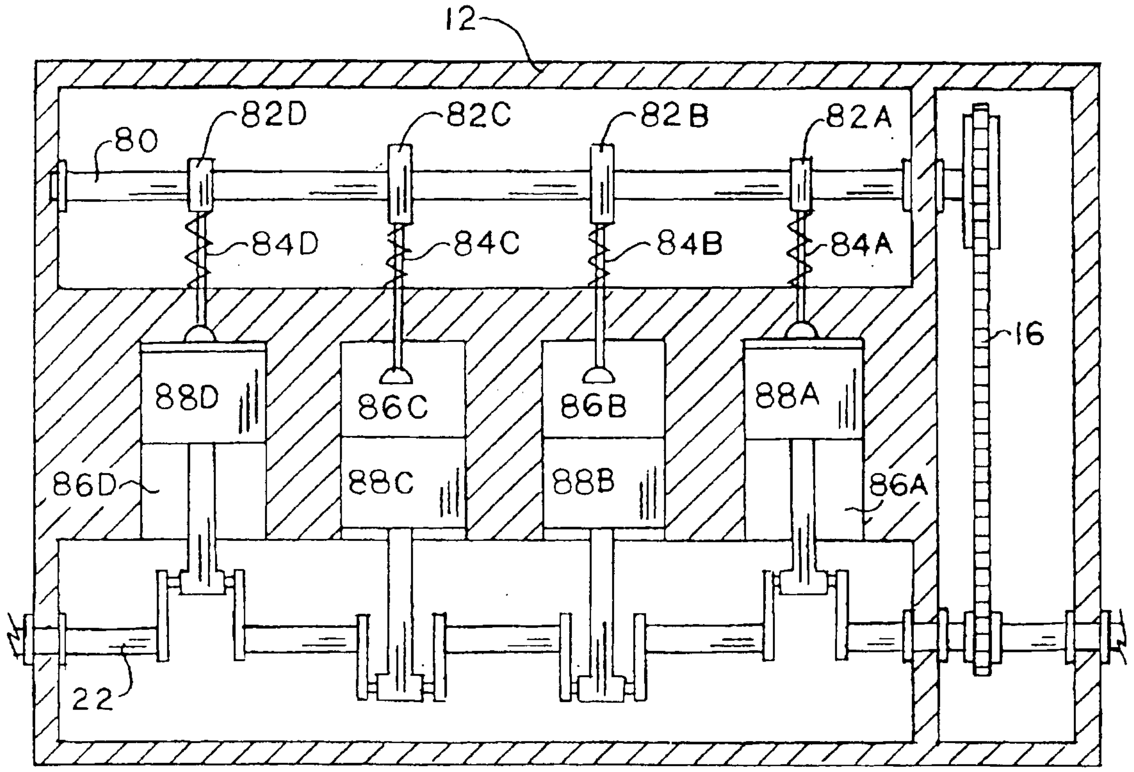


FIG. 6

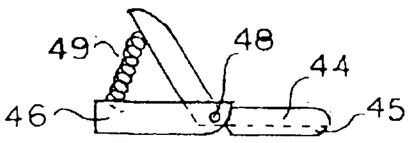
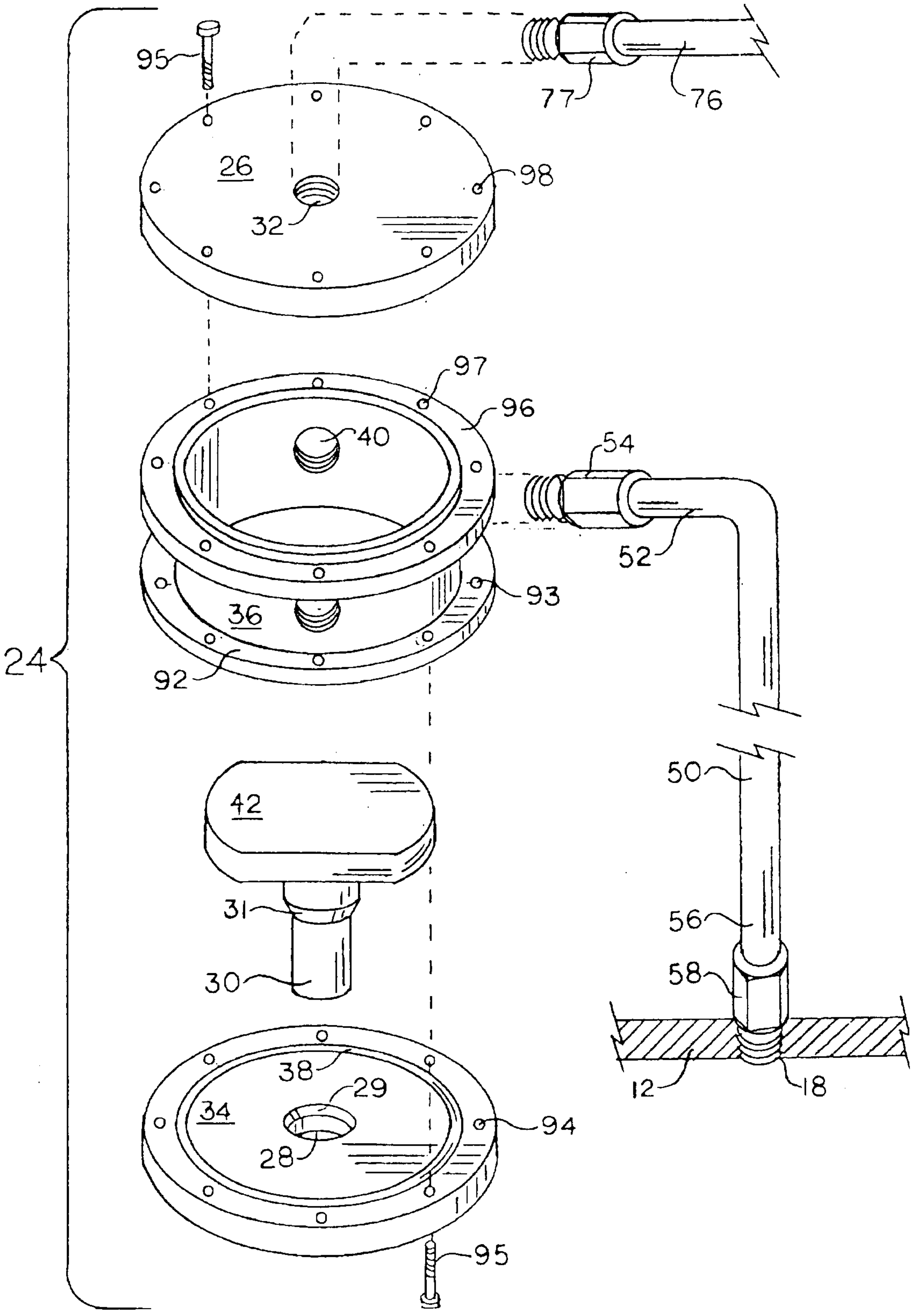


FIG. 5



APPARATUS TO CONVERT A FOUR-STROKE INTERNAL COMBUSTION ENGINE TO A TWO-STROKE PNEUMATICALLY POWERED ENGINE

RELATED U.S. APPLICATION DATA

This application is a continuation-in-part of my application Ser. No. 344,162 filed Nov. 23, 1994, now abandoned.

TECHNICAL FIELD

This invention relates to the field of combustion engines. More specifically, this invention relates to an apparatus to convert a four-stroke internal combustion engine to a two-stroke pneumatically powered engine.

BACKGROUND ART

In the field of combustion engines, it is well known that fuels such as gasoline, diesel, and ethanol are used in a combustion process to power engines. However, it is also well known that the use of such fuels generates byproducts which are harmful to the environment. Further, aside from environmental concerns, the use of such fuels is costly to the consumer.

In view of these concerns, it is desirable to at least substantially reduce, if not eliminate, the use of combustible fuels. One source of power is compressed air, or pneumatics. Several devices have been developed for using pneumatic power to operate engines. Pneumatically powered engines and devices to convert engines to pneumatic or other pressurized fluid power are known in the art, but they have not been well received by industry for several reasons.

One reason is that some of these inventions depend upon a new engine block, a very expensive and impractical idea.

Another reason is that many of these devices do not adequately address leakage problems, and engine efficiency is compromised.

Yet another reason is that several of these inventions do not eliminate the compression stroke, a severe restriction to engine operation which could only be overcome by providing extremely high pressures. But this is impractical since most compressors are designed to produce less than 200 p.s.i., 125 p.s.i. is most common.

Another reason is that several of these inventions include recirculating or recycling devices, again a significant resistant force against efficient engine operation and unnecessary in the case of compressed air since it is non-polluting.

Still another reason is that some of these inventions include somewhat complicated devices or even numerous devices for distributing and/or delivering compressed air or pressurized fluid to the cylinders.

Typical of the art are those devices disclosed in the following United States Letters Patents:

U.S. Pat. No.	Patentee	Issue Date
3,885,387	Simington	May 27, 1975
3,925,984	Holleyman	Dec 16, 1975
4,018,050	Murphy	Apr 19, 1977
4,102,130	Stricklin	Jul 25, 1978
4,162,614	Holleyman	Jul 31, 1979
4,292,804	Rogers, Sr.	Oct 6, 1981
4,596,119	Johnson	Jun 24, 1986
4,896,505	Holleyman	Jan 30, 1990
5,163,292	Holleyman	Nov 17, 1992

Simington ('387) shows an air drive adaptor consisting of a valving means for introducing compressed air to engine cylinders, however no means of eliminating the compression stroke is shown. Atmospheric air is admitted via intake valve on intake stroke, compressed during compression stroke, supplemented by compressed air via valving means for power stroke, then exhausted to atmosphere on exhaust stroke.

U.S. Pat. No. 3925984 is a compressed air power plant which uses manifold means and solenoid operated valves to deliver compressed air to cylinders. Discharged air is received in an exhaust tank and is then pumped into a high-pressure tank. This invention does not claim a means of converting a four-stroke internal combustion engine to a two-stroke engine operated by compressed air.

Murphy ('050) teaches a compressed air operated motor employing dual lobe cams using a modified camshaft to operate both intake and exhaust valves of the motor. Compressed air must be continuously supplied to the intake manifold. The large perimeter of the intake manifold must be adequately sealed to contain the compressed air. Exhausted air is recompressed. Murphy does not use a distributor. As described, this invention may require a new intake manifold, an economical disadvantage.

The invention by Stricklin ('130) converts a four-stroke internal combustion engine into a two-stroke engine powered by steam or compressed air by changing the relation of the camming action either by replacing the camshaft gear to one the same size as the crankshaft gear or by modifying the camshaft lobes to being dual-lobed. He does not use a distributor but uses the intake valves and intake ports to introduce steam or compressed air from the manifold to the cylinders. Sealing the large perimeter of the intake manifold to contain the pressure may be a significant problem. This invention includes a means of reversing the direction of the engine operation so that the transmission and/or clutch can be removed.

U.S. Pat. No. 4162614 is a pressure fluid operated power plant that includes a distributor which simply splits the main supply line into a plurality of supply lines, one for each cylinder of the engine, an actuating valve for each individual supply line, and a unitary inlet and exhaust valve, or spool valve, for each cylinder to control the intake and exhaust of pressure fluid. As shown, the engine is not a converted four-stroke internal combustion engine, but a different engine with the crankshaft configured so that the pistons do not operate in pairs and without the standard engine valves. Also, fluid exhaust goes into a tank to be recycled for re-use or for use elsewhere.

Rogers, Sr. ('804) shows electrically operated valve actuating means to control the intake of compressed gas to the cylinders. He also provides for recycling at least a portion of the gas exhausted to be recompressed or to cool transmission fluid or to be used as a working fluid in an air conditioning system. The valve actuator operates only one valve at a time and therefore only one cylinder receives compressed gas. Applied to a typical engine, the compression stroke is not eliminated. No provision is made to convert the engine to a two-stroke operation. This invention also uses altering means for increasing the duration of each engine cycle over which the valve means admits compressed gas to the at least one cylinder as the speed of the engine increases. However, compressed gas must be supplied during the entire power stroke, regardless of the speed of the engine.

Johnson ('119) teaches a compressed air propulsion system for a vehicle which includes an air distributor system comprising a plurality of solenoids and electrically operated microswitches to operate air supply intake valves. Johnson does not show a means of eliminating the compression stroke, that is, he is not converting a four-stroke engine to two-stroke operation.

U.S. Pat. No. 4896505 is a pressurized fluid operated engine that includes a rotary type distributor which supplies pressurized fluid to the engine cylinders via spool valves which control both intake and exhaust. This invention includes a recirculation means for recycling at least a portion of exhaust gas. Holleyman attempts to address the resulting resistance to engine operation by describing ejector means. The rotary distributor means as described and shown would present problems relating to leakage to other than the desired supply line and if tightly assembled to reduce leakage, friction would be created, and therefore heat and resistance. As with his earlier patents, Holleyman is not converting a typical four-stroke engine to a two-stroke operation for pressurized fluid. He does not show the standard configuration of the crankshaft whereby pistons move in pairs and does not show the engine's intake and exhaust valves.

U.S. Pat. No. 5163292 shows the rotary distributor of Holleyman's previous patent has been modified to lengthen the amount of time that pressurized fluid is permitted through each supply line to a cylinder via a pressure sensitive snap action diaphragm valve. However there has been no modification made to the rotary distributor to address the problem of pressurized fluid leakage to undesired supply lines. The diaphragm valves replace the former spool valves for controlling intake and exhaust of pressurized fluid. Exhaust pressure must exceed inlet pressure for valves to operate on the exhaust stroke and this could cause some resistance. Holleyman also includes a fluid mixing means used to recycle spent fuel. Like his previous patents, Holleyman does not claim to be converting a combustion engine to a two-stroke operation to use pressurized fluid.

In view of the prior art, it is the main object of this invention to provide an improved apparatus to convert a four-stroke internal combustion engine to a two-stroke pneumatically powered engine which minimizes the aforementioned problems, that is, leakage and resistant forces are eliminated thereby achieving the maximum efficiency and performance of the engine.

It is another object of this invention to provide an apparatus to convert a four-stroke internal combustion engine to a two-stroke pneumatically powered engine in order to preserve natural resources.

It is a further object of the present invention to provide an improved pneumatic distributor for mounting on an existing timing mechanism of an engine, the pneumatic distributor operating in similar fashion to conventional electrical distributors while eliminating the need for electrical current thereto.

Another object of the present invention is to provide an apparatus to convert a four-stroke internal combustion engine to a two-stroke pneumatically powered engine while retaining a substantial portion of the existing parts of the engine, thereby minimizing the costs involved in such conversion.

Still another object of this invention is to provide an apparatus to convert a four-stroke internal combustion engine to a two-stroke pneumatically powered engine such that air and noise pollution created by the operation of the engine is substantially reduced.

Yet another object of the present invention is to provide such an apparatus to convert a four-stroke internal combustion engine to a two-stroke pneumatically powered engine whereby the cost of operation of the engine is substantially reduced.

Other objects and advantages will be accomplished by the present invention which serves to replace combustible fuel systems associated with the operation of an engine. Thus, the present invention is designed to preserve natural resources which are rapidly being depleted.

BRIEF SUMMARY OF THE INVENTION

The apparatus to convert a four-stroke internal combustion engine to a two-stroke pneumatically powered engine is comprised generally of a pneumatic distributor, a modified dual-lobed camshaft for operation of the exhaust valves, at least one air compressor, at least one compressed air holding tank, and a regulator to control the pressure and volume of compressed air being delivered to the engine. An air compressor is driven using the rotation of the crankshaft. Compressed air is delivered from the compressor through a supply line to at least one holding tank. A supply line is provided for delivering compressed air from the tank to the engine. After passing through the regulator, the compressed air enters the pneumatic distributor. A plurality of high pressure hoses is provided for finally communicating the compressed air to the cylinders of the engine via the spark plug orifices. The pneumatic distributor has a rotor mountable to the existing timing mechanism, and the rotor opens the gate valves to supply compressed air to the cylinders wherein the pistons are at top dead center, making every downstroke a power stroke. The modified dual-lobed camshaft operates the exhaust valves so that every upstroke of a piston is an exhaust stroke, and exhausted air freely escapes through the exhaust manifold.

BRIEF DESCRIPTION OF THE DRAWINGS

The above mentioned features of the invention will become more clearly understood from the following detailed description of the invention read together with the drawings in which:

FIG. **1** is a diagrammatic top plan view of a typical four-stroke internal combustion engine converted to a two-stroke pneumatically powered engine using the apparatus of this invention.

FIG. **2** is an enlarged top plan view of the pneumatic distributor of the apparatus of this invention with its upper housing member removed.

FIG. **3** is a fragmentary sectional view of the modified dual-lobed camshaft of the apparatus of this invention.

FIG. **4** is a longitudinal vertical cross-sectional view taken through a typical four cylinder engine converted to a two-stroke pneumatically powered engine using the apparatus of this invention.

FIG. **5** is an exploded view of the pneumatic distributor constructed in accordance with this invention.

FIG. **6** is an enlarged top edge view of the gate valve assembly of the pneumatic distributor.

DESCRIPTION OF THE PREFERRED EMBODIMENT

An apparatus to convert a four-stroke internal combustion engine to a two-stroke pneumatically powered engine incorporating various features of the present invention is illustrated generally at **10** in the figures. The apparatus to convert a four-stroke internal combustion engine to a two-stroke pneumatically powered engine, or apparatus **10**, is designed for replacing combustible fuel systems associated with the operation of an engine **12**. In so doing, in the preferred embodiment the apparatus **10** is designed to preserve natural resources which are rapidly being depleted.

As illustrated in FIG. **1**, the apparatus **10** of the present invention is comprised generally of a pneumatic distributor **24**, a modified dual-lobed camshaft **80**, at least one air compressor **60**, at least one compressed air holding tank **68**, and a regulator **20**. The apparatus **10** is used in conjunction with a conventional four-stroke internal combustion engine **12** in lieu of several conventional components. Namely, the carburetor, the original camshaft, the electric distributor, the spark plugs, spark plug wires, fuel pump, fuel lines, fuel tank, and the emissions control system are several of those removed components.

An air compressor **60** is operated using the rotation of the crankshaft **22**. A crankshaft pulley **66** is provided for engaging a belt **64**, the belt **64** being provided for driving the pressure sensor clutch **62** provided by the air compressor **60**. When the engine **12** is running, the air compressor **60** is continually compressing air into at least one compressed air holding tank **68** through a check valve **72** and supply line **74**. Air is being compressed by the air compressor **60** even while the engine **12** is idling such that the compressed air supply is continuously being replenished. The tank **68** is provided with a bleeder valve **70** to evacuate any condensation collected therein.

A supply line **76** is provided to deliver compressed air from the tank **68** to the engine **12**. Upon exiting the tank **68**, the compressed air is delivered through a regulator **20**, which controls the pressure and volume of the compressed air, and passes through the supply line **76** to a pneumatic distributor **24**.

The pneumatic distributor **24** is shown in FIGS. **2** and **5**. The pneumatic distributor **24** is comprised of a lower housing member **34**, a center housing member **36**, a plurality of gate valves **44**, a rotor **42**, and an upper housing member **26**.

The lower housing member **34** has a through opening **28** with a beveled top edge **29** for receipt of the rotor mount **30** of the rotor **42**, a plurality of bolt holes **94** radially spaced near the outer perimeter, and a groove **38** for receipt of a seal (not shown) and the bottom edge of the center housing member **36**.

The rotor **42** has a rotor mount **30** with a beveled portion **31** to be closely received by the through opening **28** and its beveled top edge **29** of the lower housing member **34**.

The upper housing member **26** defines a threaded inlet portal **32** for receipt of fitting **77** on compressed air supply line **76**, a plurality of radially spaced bolt holes **98**, and a groove on its underside, not visible but essentially the same as groove **38** in the lower housing member **34**, for receipt of a seal (not shown) and the top edge of the center housing member **36**.

The center housing member **36** is cylindrically shaped with a lower protruding portion **92** having radially spaced threaded bolt holes **93** to coincide with bolt holes **94** of lower housing member **34**, an upper protruding portion **96** having radially spaced threaded bolt holes **97** to coincide with bolt holes **98** of upper housing member **26**, a plurality of radially spaced threaded portals **40** for passage of compressed air to the individual cylinders **86**. A gate valve mounting means **46** is secured to the inner wall of the center housing member **36** adjacent to each portal **40**. As shown in FIG. **6**, each gate valve **44** has a seal **45** for sealing portal **40** and a return spring **49** and is attached to the mounting means **46** by means of a pivot pin **48**.

A plurality of high pressure hoses **50** is provided for finally communicating the compressed air to the individual cylinders **86** of the engine **12**. Each high pressure hose **50** is provided at one end **52** with a threaded fitting **54** for engaging a threaded portal **40** defined by the center housing member **36**, and at the other end **56** with a threaded fitting **58** for engaging the threaded spark plug orifice **18** defined by the engine **12**. Thus the threaded fitting **58** is substantially similar to the threaded portion defined by a conventional spark plug. High pressure hoses **50** are connected to the individual cylinders **86** in the same order as conventional spark plug wires such that a proper sequence of compressing the pistons **88** downward in their respective cylinders **86** is accomplished.

As shown in FIG. **1**, the pneumatic distributor **24** may be located at the existing distributor mount **14** of the engine **12**. The rotor mount **30** is received by the through opening **28** of the lower housing member **34** and engaged by the existing timing mechanism **16**. The center housing member **36** is secured to the lower housing member **34** by means of bolts **95** received by bolt holes **94** of the lower housing member **34** and the threaded bolt holes **93** of the center housing member **36**. The upper housing member **26** is secured to the center housing member **36** by means of bolts **95** received by bolt holes **98** of the upper housing member **26** and the threaded bolt holes **97** of the center housing member **36**.

FIG. **2** shows the pneumatic distributor **24** for a four cylinder application. As the existing timing mechanism **16** of the engine **12** is operating, the rotor **42** is continuously rotating and opening a pair of gate valves **44** to supply compressed air via portals **40** and high pressure hoses **50** to a pair of cylinders **86**, (in FIG. **4**, cylinders **86**A and **86**D), and thereby creating a power stroke to the pair of pistons **88** (in FIG. **4**, pistons **88**A and **88**D) which are beginning the downstroke. As the rotor **42** continues to rotate, the rotor **42** releases one pair of gate valves **44** and engages the remaining pair. The return spring **49** closes the released gate valves **44** and the seal **45** ensures no compressed air can enter the associated portals **40**.

If constructed as shown in FIG. **5**, the pneumatic distributor **24** can be used on any four cylinder engine (or with six portals **40**, on any six cylinder engine, etc.). FIG. **2** shows rotor **42** must rotate clockwise to open gate valves **44**, but if the timing mechanism **16** requires counter-clockwise rotation, this can be accomplished by attaching center housing member **36** up-side-down. Only the rotor mount **30** for engaging the timing mechanism **16** may be different for another model engine. The upper housing member **26** and the lower housing member **34** can be used for any number of cylinders and the center housing member can be made with any appropriate number of portals **40**.

The modified dual-lobed camshaft **80** replaces the original camshaft of the engine **12**. The modified dual-lobed camshaft **80** operates only the exhaust valves **84** of the engine **12** and has a dual-lobed cam **82**, as shown in FIG. **3**, for each exhaust valve **84**. As shown in FIG. **4**, dual-lobed cams **82**B and **82**C are arranged to engage a pair of exhaust valves **84**B and **84**C of a pair of cylinders **86**B and **86**C on every upstroke of the associated pair of pistons **88**B and **88**C. Exhausted air freely escapes through existing exhaust ports (not shown) and exhaust manifold **90**. As the modified dual-lobed camshaft **80** turns, the cams **82**B and **82**C disengage exhaust valves **84**B and **84**C, which close, and cams **82**A and **82**D engage and open exhaust valves **84**A and **84**D.

The pneumatic distributor **24** in combination with the modified dual-lobed camshaft **80** effectively converts a four-stroke engine operation to a two-stroke engine operation, that is, retaining the power stroke and the exhaust stroke while eliminating the intake stroke and the compression stroke. The result is that the engine functions at the maximum efficiency and performance possible.

While a preferred embodiment has been shown and described, it will be understood that it is not intended to limit the disclosure, but rather it is intended to cover all modifications and alternate methods falling within the spirit and the scope of the invention as defined in the appended claims.

Having thus described the aforementioned invention,

I claim:

1. An apparatus to convert a four-stroke internal combustion engine into a two-stroke pneumatically powered engine, said combustion engine including at least one original camshaft, a timing mechanism, and a plurality of cylinders, each of said cylinders receiving a piston for reciprocating movement therein, each of said cylinders being provided with a spark plug orifice conventionally receiving a spark plug, each of said cylinders having at least one exhaust valve, said apparatus comprising:

at least one compressed air holding tank;

at least one air compressor for compressing air and delivering said compressed air to said at least one tank;

a compressed air supply line being in fluid communication between each of said at least one air compressor and each of said at least one tank;

a pneumatic distributor for receiving said compressed air from said at least one tank and distributing said compressed air to at least one of said cylinders in an order predetermined by said timing mechanism of said pneumatic engine, said pneumatic distributor including an upper housing member, a center housing member, a lower housing member, a rotor, and a plurality of gate valves, said lower housing member having a through opening to receive said rotor, said rotor being mounted to said timing mechanism, said upper housing member having an inlet portal for introducing said compressed air to said pneumatic distributor, said center housing member having a plurality of radially spaced portals, each of said portals of said center housing member having one of said plurality of gate valves, each one of said plurality of gate valves having a mounting means, a pivot pin, a return spring, and a seal, said rotor being operated by said timing mechanism and thereby opening at least one of said plurality of gate valves to supply said compressed air to each of said cylinders wherein said pistons are at top dead center thereby creating the power stroke of said pistons;

a compressed air supply line being in fluid communication between said at least one tank and said inlet portal of said upper housing member of said pneumatic distributor;

a plurality of compressed air supply lines, one each being in fluid communication between one of said plurality of portals defined by said center housing member of said pneumatic distributor and one of said spark plug orifices; and

a modified dual-lobed camshaft to be used in said pneumatic engine in place of said original camshaft of said combustion engine for operating said exhaust valves during every upstroke of said pistons,

2. The apparatus of claim **1** further comprising a regulator in fluid communication between said at least one tank and said pneumatic distributor for varying the pressure and volume of said compressed air in order to control the operating speed of said pneumatic engine.

* * * * *

US006006519A

United States Patent [19]

Hormell, Jr.

[11] **Patent Number: 6,006,519**

[45] **Date of Patent: Dec. 28, 1999**

[54] **COMPRESSED AIR-POWERED ENGINE**

[76] Inventor: **Jack V. Hormell, Jr.**, P.O. Box 546,
Moncks Corner, S.C. 29461

[21] Appl. No.: **08/986,367**

[22] Filed: **Dec. 8, 1997**

[51] **Int. Cl.**^{6} **F16D 31/02**

[52] **U.S. Cl.** **60/407**; 418/61.2

[58] **Field of Search** 60/407; 418/61.2

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,292,804	10/1981	Rogers, Sr.	60/407
4,386,890	6/1983	Berkowitz	418/61.2
4,487,561	12/1984	Eiermann	418/61.2
5,251,596	10/1993	Westland	418/61.2 X
5,515,675	5/1996	Bindschatel	60/407 X

Primary Examiner—Hoang Nguyen

[57] **ABSTRACT**

An internal combustion engine is disclosed that runs efficiently on compressed air supplied by air compressors. The preferred power plant for the instant invention air powered engine is the Wankel-type rotary engine. The air compressors which supply the air "fuel" to the engine chamber where the air is re-compressed to provide the force for "pushing" the rotors within the chamber which rotational movement provides the power to turn the drive shaft. These air compressors may be electrically and/or mechanically driven.

7 Claims, 3 Drawing Sheets

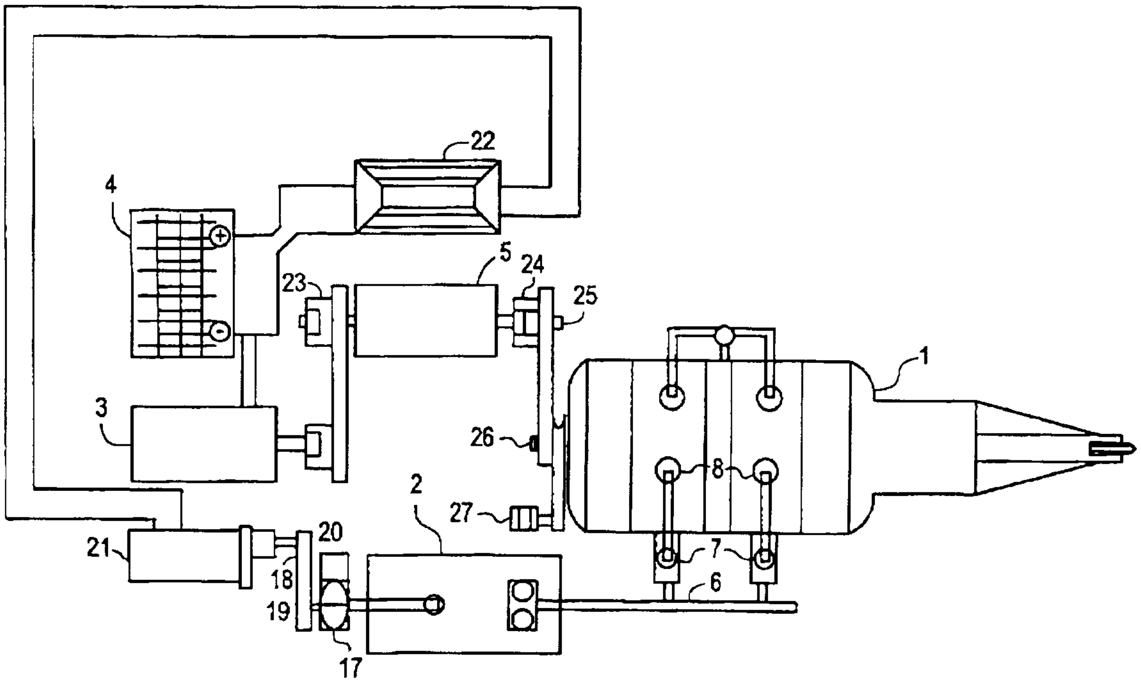


FIG.1

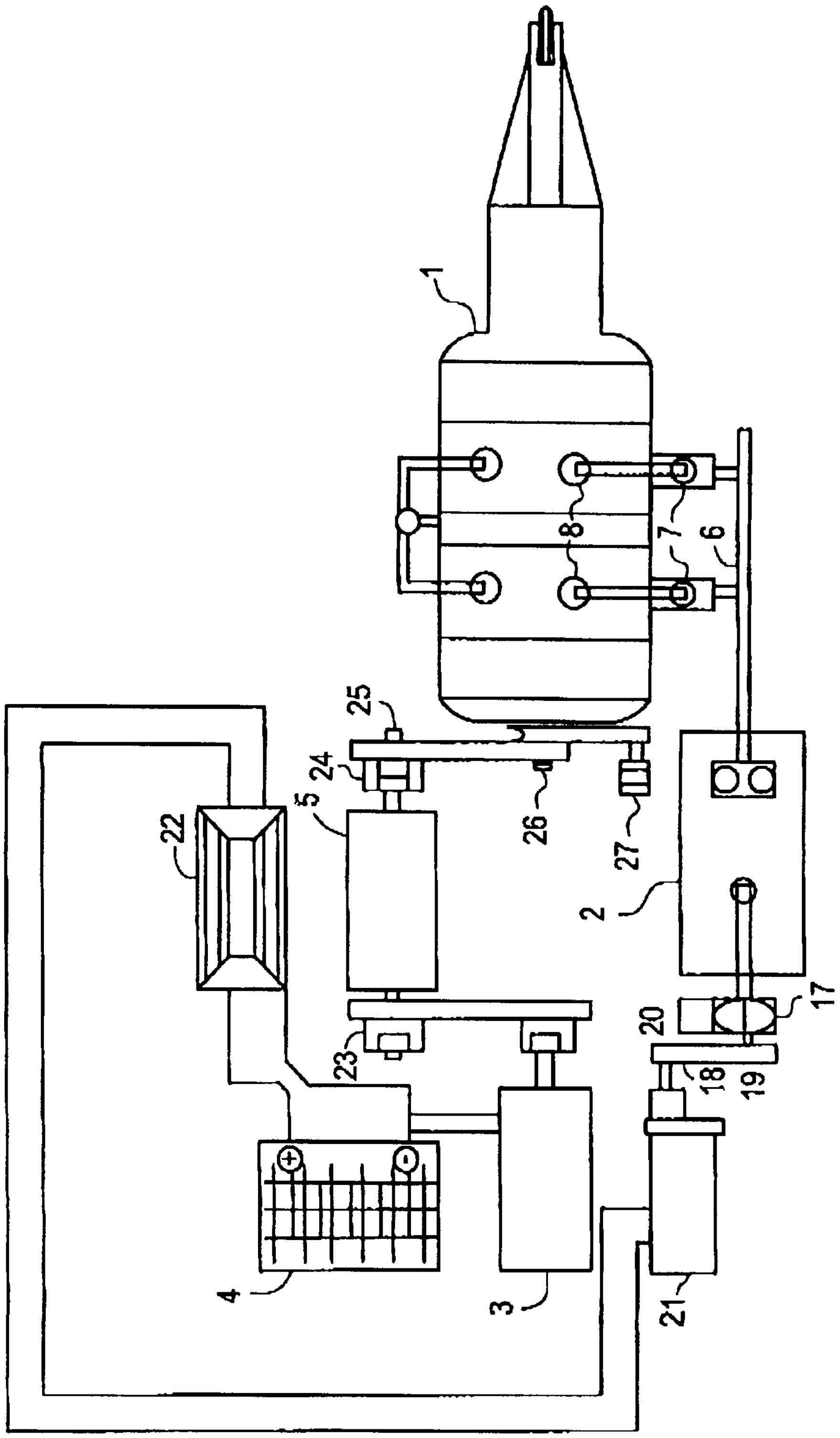


FIG.2

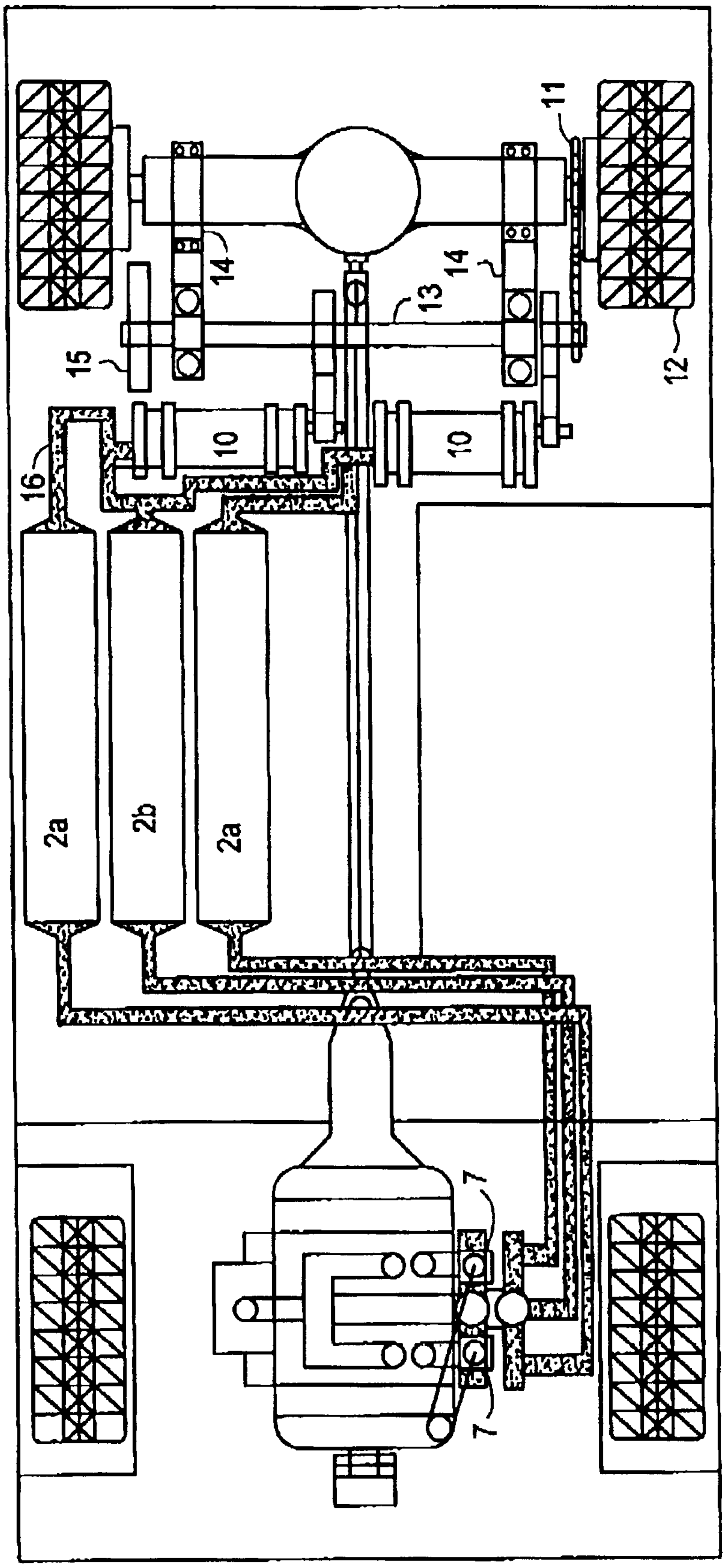


FIG.3A

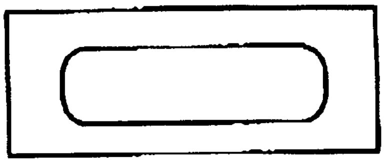


FIG.3B

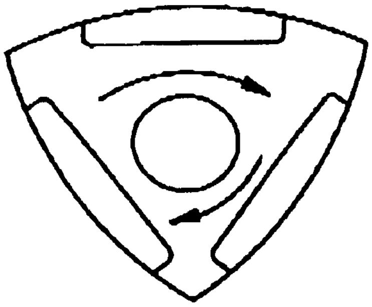


FIG.4A

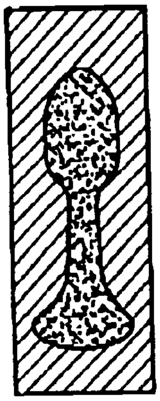
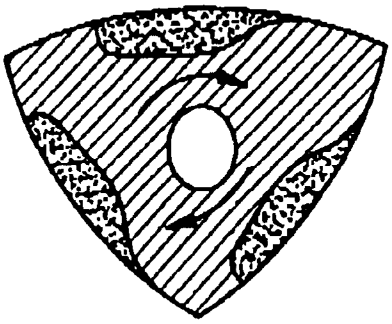


FIG.4B



COMPRESSED AIR-POWERED ENGINE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates generally to compressed air engines. Particularly, it relates to such an engine capable of maintaining the pressure in its supply tank at a predetermined level for efficient and continuous operation. More particularly, one embodiment of the instant invention relates to an adaptation of the Wankel-type rotary engine which adaptation enhances engine efficiency for using compressed air as its force of propulsion.

2. Description of Related Art (Including Information Disclosed Under 37 CFR 1.97 and 1.98)

In spite of their many benefits, internal combustion engines for powering motor vehicles and fossil fuel burning plants used in energy producing operations throughout the industrialized nations have been under attack for many years because of their inherent characteristics which produce air and other pollutants. This is due, of course, to the nature and required volumes of the fossil fuel needed to produce the necessary power for the various uses to which the engines are put, not the inherent design of the engine itself. Much research has been devoted to increase the combustion efficiency and filter the exhaust from these power plants with a view to "saving" the atmosphere through more efficient and cleaner burning. In particular, various steps have been taken by the automotive industry to reduce fuel consumption by automobiles. For example, computer monitoring of internal combustion engine functions and fuel flow has resulted in the production of a more complete combustion of the air fuel mixture after it enters the combustion chamber of the internal combustion engine. Once the gas is burned and subsequently exhausted, it is then filtered through a catalytic converter which removes additional pollutants before the exhaust is expelled into the atmosphere. The relative successes of such operations, however, have been incrementally slow and limited.

One of the approaches taken in the production of a completely clean power plant is the design of an air powered engine which is, of course, completely pollution free, since there are absolutely no combustion gasses generated and released into the atmosphere. However, design in this area has been somewhat limited because of the reduced power output capable for such engines and because of their somewhat inefficient and complex operations. The air engine, therefore, has seen only limited use in some cases as an auxiliary power plant with a combustion engine as the primary power source, or more often it has been abandoned entirely in favor of other systems because of the auxiliary power needed to maintain an adequate supply of air pressure for the system.

Various attempts to successfully develop commercial air engines include:

U.S. Pat. No.	Title
3,765,180	Compressed Air Engine
3,925,984	Compressed Air Power Plant
4,102,130	Converting An Internal Combustion Engine to a Single Acting Engine Driven by Steam or Compressed Air
4,104,955	Compressed Air-Operated Motor Employing an Air Distributor
4,124,978	Compressed Air Engine
4,311,084	Pneumatic Engine
4,370,857	Pneumatic System for Compressed Air Driven Vehicle
4,478,304	Compressed Air Power Engine
4,590,767	Hot Gas Engine and Vehicle Driven System
4,596,119	Compressed Air Propulsion System for a Vehicle
4,651,525	Piston Reciprocating Compressed Air Engine
5,154,051	Air Liquefier and Separator of Air Constituents for a Liquid
5,491,977	Engine Using Compressed Air
5,638,681	Piston Internal-Combustion Engine
5,680,764	Clean Air Engines Transportation and Other Power Applications

The devices described by the above-recited patents fall far short of commercial practicality. If they are pollution-free they are too complicated, and, if simple, they are not pollution-free.

Therefore, it is an object of this invention to provide a relatively simple, efficient non-polluting air-powered engine, which produces power sufficient to attain driving speeds comparable to or greater than conventional fossil fuel powered engines.

Another object of this invention is to provide such an air powered engine which makes use of an auxiliary air compressor having an auxiliary compressor to fill a compressed air supply tank up to a predetermined minimum level and as the engine consumes air from the supply tank, the auxiliary compressor is again driven for recharging the compressed air supply tank to continue to build up to a maximum predetermined air pressure level, thereby maintaining this level for smooth running operation.

SUMMARY OF THE INVENTION

It has been discovered that an internal combustion engine runs efficiently on compressed air that is supplied by air compressors. Most standard, fossil fuel burning combustion engines can be suitably converted to be powered by air pursuant to the present invention. The Wankel-type rotary engine, however, is the preferred power plant for adaptation to present invention air powered engine. The air compressors which supply the air "fuel" to the engine chamber where the air is used to provide the force for "pushing" rotors within the chamber which rotational movement turns the drive shaft, which operates through a transmission to turn the drive axle to move the vehicle. These air compressors may be electrically and/or mechanically driven.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic view showing the various parts of the compressed air engine and related electrical system in accordance with the present invention; and

FIG. 2 is a top plan view of an alternative engine and air compressor configuration, without a related electrical system.

FIG. 3. is a cross-section view of a conventional Wankel-type rotary engine block.

FIG. 4 is a cross-section view of a Wankel-type rotary engine block adapted to enhance the clockwise rotation of the rotors.

DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

The fuel system of the disclosed invention is effective for basically any internal combustion engine, including both two-stroke and four-stroke engines as well as a rotary engine, such as the familiar Wankel-type rotary engine. The compressed air used to supply the "fuel" in compressed air-powered engines of the type mentioned is supplied preferably by a bank of air compressors of either the reciprocating or screw type, depending on the application. Such powered engines may be used for: aircraft, including rotorcraft and fixed-wing aircraft; land-based vehicles, including cars, trucks, vans, motorcycles, buses, and heavy equipment; watercraft, including boats, jet skis, hydrofoils, and hovercraft; and industry applications, such as in multiple uses in factories, for pumping production wells in the oil fields, or in stores and homes to power air conditioning systems.

Compressors used to supply the compressed air to run the internal combustion engines are ideally located onboard the vehicle being powered or near the engine it is fueling. These compressors can be driven by a variety of different set up variations, either mechanical or electrical, or both. They can be driven by belts, chains, or direct drive (i. e., gears) depending on the application. Certain configurations, it is submitted, cause the engine that is being fueled to be relatively self-sustaining.

The invention is described herein primarily in reference to FIGS. 1 and 2.

Although any standard internal combustion engine can be adapted to serve as the basis for the invention air powered engine, FIG. 1 employs the Wankel-type rotary engine 1 as the basis for the preferred embodiment of the present invention. As disclosed herein the "fuel" for the invention air powered engine is provided by compressed air receiver and storage tanks. Primary and secondary (as backup) air receiver/storage tanks are preferably employed as the source of compressed air to power the engine. Continuing in regard to FIG. 1, at least one primary air receiver/storage tank 2 is used as part of the primary air "fuel" system. It is preferable to employ multiple primary air receiver and storage tanks of optimal size for needed on-call engine demand and vehicle configuration. An additional air storage tank, preferably 10-gallon, is preferred as an internal part of the secondary backup air fuel system. Both the primary and the secondary backup air storage systems are pre-filled to a maximum predetermined air pressure.

A preferred embodiment of the invention incorporates a Wankel-type rotary engine of the type manufactured by Mazda for its RX-7 vehicles and generally conforms to that described in U.S. Pat. No. 3,688,749 to Wankel comprising a three-lobed trochoidal peripheral engine housing, which disclosure is incorporated herein by reference. The most preferred engine for the invention compressed air-powered engine is a two-rotor Wankel rotary 12A engine. Its normal 12-volt electric starting motor **3** starts the engine, which starting motor is battery-driven **4**. The battery's electric charge is maintained via a 12-volt alternator **5**. The starter motor is engaged when a starter button or key is engaged, thus closing the 12-volt electrical circuitry, which in turn causes the starter motor to rotate. This rotation engages the starter motor's Bendix spring and gear assembly with the rotary engine's flywheel and gear assembly, causing the rotary engine crankshaft and multiple rotor assemblies to spin.

Once the engine is rotating, pressurized air from the primary air storage tank(s) **2** flows via high-pressure airlines into an air intake manifold **6**. The pressurized air, upon entering the manifold, flows through an air pressure monitoring valve **7** and into an engine RPM throttle control valve **8**, which is attached to the remaining portion of the air manifold directly connected to each of the two independent rotary engines' rotor housings. The air intake manifold **6** is attached to each of the rotary engine's housings at specific predetermined locations. The air travels through the RPM throttle control valve and throughout the remaining portion of the air manifold.

Located at the ends of the air manifold outlets are two 12-volt solenoid valves, one for each of the rotor housings. These valves are attached to the air inlets located on the rotor housings at specific points as previously stated. A modified Mazda dual-point distributor controls these 12-volt solenoid valves. The distributor is timed with the 12-volt solenoid valves to open at a predetermined specific degree of rotation of each of the engine's rotors. The 12-volt solenoid valve then stays open for a predetermined duration before the valve is closed. The timing between the 12 volt solenoid valves and the distributor is a critical part of the mechanics that allow this air-driven rotary engine to function. This action occurs on each of the rotor housings. Once rotation of the engine begins, the starter motor **3** then disengages from the engine's flywheel and gear assembly. The engine continues to run on compressed air from a primary air storage tank **2**.

From this point, reference is primarily directed to FIG. **2**, unless otherwise noted.

The pressure monitoring valves **7** continually read line pressure from the primary air tank's storage system. In the configuration of FIG. **2**, the primary air storage system is an assembly of three 20-gallon storage tanks. Two of these tanks **2***a* are being utilized as the main source of air power to run the engine. The third tank **2***b* is activated when more air pressure is required, for example, during rapid acceleration. The air pressure-monitoring valve determines when to activate the third tank and when to shut it off. This valve also selects one primary storage tank at a time to feed the engine's air requirements.

When the pressure in the primary air storage tank drops to a predetermined minimum pressure, the air pressure monitoring valve shuts down that primary air storage tank system, and it opens the second primary air storage tank system to keep the engine in operation. This action allows the first primary air storage tank that was originally utilized to be refilled along with the possible third air storage tank, if any of its air has been used. The air replenishment system that keeps the primary air storage tanks full is a design which uses the forward momentum of the vehicle to drive an independently designed system. This independently designed system operates two rotary screw air compressors **10** which are attached to the three primary air storage tanks (**2***a* and **2***b*) in a specific configuration which basically breaks the primary air supply system into two independent, but equal, compressed air fuel supplies. The forward momentum of the vehicle which drives the rotary screw type compressors **10** is harnessed by attaching one end of a gear and chain assembly **11** to the vehicle's left rear wheel **12**, and the other end of the chain is attached to a live axle assembly **13** located inside the vehicle. The left rear wheel is used because in a standard differential rear end, the drive, or power, wheel of the vehicle is usually the right rear wheel, so that energy is not directly consumed from the drive wheel. The gear is attached to the left rear wheel by way of a special mounting system as the gear drives the chain, which enters the car through an opening in the car's floorboard. The chain is attached to a floating live axle assembly **13** located inside the vehicle directly above and slightly forward of the rear axle housing. This floating live axle is attached to the car's original rear axle housing by a special bracket and platform assembly **14**. This attachment makes allowance for any rear wheel suspension movement and therein eliminating any interference with the live axle mounted inside the vehicle due to suspension travel. Attached to the right side of the live axle is a flywheel **15**, which aids in axle rotation and enhances axle momentum. As noted, attached to this live axle by either belt or chain drives are the two rotary screw compressors **10**. By way of example, compressors **10** could be 10HP Ingersoll Rand #EP20-ESP/BM, 4P984 rotary screw air compressors that will produce 35.0 CFM at 125 PSI at a variable air outflow rate. In a preferred configuration shown in FIG. **2**, each of the two compressors is attached to a separate primary 20-gallon air storage tank and to the same third primary air storage tank by high-pressure airlines **16**. The separate air power sources replenish the supply of air to the primary air storage system. By using the live axle compressor drive, air to run the engine is produced. (Thus, the movement powered by the air fed into the engine is used to produce more compressed air "fuel." When the vehicle is stopped after travelling a distance, the air receiver/storage (or, fuel) tanks will be as full as when the journey began.) These rotary screw type compressors 10 will also be vented with pop-off valves that may be necessary because of the high output of the compressors which will cause the storage tanks to fill very quickly. The pop-off valves can vent the excess air externally. Should the excess air be of sufficient volume and pressure, the entire system can be modified to form a closed loop air replenishment system. A pressure control valve connected to an on/off switch which would turn the compressors on/off as needed monitors compressor. This primary air supply system when added to the backup secondary air supply system will make this engine and the compressed air fuel supply system effectively self-sustaining.

The two-rotor Wankel rotary 12A engine can be started by air pressure alone, taking the 12 volt battery and starter out of the system completely. Again, the fuel that is used to cause the two rotor Wankel rotary engine to run is compressed air. Referring again to the configuration shown in FIG. **1**, the compressed air is stored in a compressed air storage tank **2**, which may be a 10-gallon capacity air storage tank. This 10-gallon air storage tank **2** is filled with compressed air from a 0.5 horsepower, 125 PSI reciprocating air compressor **17**. This 0.5 horsepower 125 PSI reciprocating air-compressor is driven via a belt pulley system, including a belt **18**, a pulley **19** on the compressor side, and a pulley on the gear reduction electric motor side **20**. This belt pulley system **18**–**20** that is attached to the AC gear reduction electric motor **21** rated at 0.5 horsepower input will, through gear configuration produce, 1,725 RPM output (which translates to 2.5 horsepower at 1250 RPM). This AC electric gear reduction 0.5 horsepower motor **21** is being fed by an electrical inverter number PV I—NT 12OOFC **22** which is rated at 12 volt DC, 130 Amps, 230 volts, 1200 watts. This inverter is connected preferably to a 12 volt 680 Amps marine type battery **4**. Also within the circuitry of the inverter and battery there is placed a 12 Volt 140 Amp alternator **5**. This alternator is designed in such a way so that the drive shaft running through the armature shaft exits both sides of the alternator. Thus, producing two additional power drive sources. On the drive shaft exiting the alternator at the front will be attached an electric clutch **23**. The other end of the shaft exiting the rear of the alternator an additional electric clutch **24** will be attached. However, to this clutch there will also be a V type pulley **25** attached to clutch **24**. This electric clutch and pulley assembly will be directly connected to the crank shaft harmonic balancer pulley assembly **26** on the front of the Wankel Rotary Engine by way of a V type belt. The clutch assembly is wired to a 12 volt DC motor that runs at 2,350 RPMS. Attached to its output shaft there is another electric clutch **27** that is wired to clutch **23**.

The open chamber (or, combustion chamber) is preferably modified from the stock Mazda design. It is recommended to change the internal configuration from the conventional elongated rectangle with round corners of FIG. **3**, because when the spark plugs fire (a primary, or leading A, and secondary, or trailing B) B is directly above A on the rotors of a Mazda Rotary Engine.

The geometry of this combustion chamber may be improved for enhanced performance, especially with the compressed air system. When the spark plugs fire, first A then B, in a uniformly equal design combustion chamber, rotor rotation direction is compromised as the rotor rotates in a clockwise direction. Spark plug A fires as the combustion chamber passes; then, spark plug B fires in the same combustion chamber to achieve a more complete burn of the air-fuel mixture.

However, because of the rotor configuration when spark plug B fires, the rotor hesitates and tends to be pushed in a counterclockwise direction. Because of the rotor's gearing and the timing of spark plug A, the rotor continues rotating in its clockwise direction, but only because of the timing of the second rotor.

The new combustion chamber design shown in FIG. **4** enhances the clockwise rotation. By gradually building up the walls at the forward (to the direction of rotation) end of the combustion chambers and altering the geometry of the internal open space, an even greater compression effect of the compressed air is given. This results in elimination of the apparent hesitation when spark plug A fires and facilitates a faster clockwise rotation. The new and improved combustion chamber design compliments the already inherent clockwise rotation for which the engine is designed.

Many modifications and variations of the present invention will be apparent to one of ordinary skill in the art in light of the above teachings. It is therefore understood that the scope of the invention is not to be strictly confined to the literal limitations of the claims appended hereto.

What is claimed is:

1. An engine powered solely by compressed air comprising:

(a) an engine block comprising an external wall having air intake manifolds connected therewith for receiving compressed air, an internal wall defining an open chamber therein which is further defined by multiple confined areas, which are defined by the internal open chamber wall and multiple rotateably moveable elements within said open chamber, whereby the expansion of compressed air within said confined areas causes movement of said moveable elements, wherein the open chamber is trichoidal in shape and the moveable elements are rotors;

(b) a driveshaft connected to said multiple moveable elements such that movement of said elements within the internal open chamber causes said driveshaft to rotate around its linear axis;

(c) means for starting the engine;

(d) means for supplying compressed air; and

(e) high pressure airlines from compressed air supply means to said air intake manifolds.

2. The engine of claim **1** wherein the compressed air supply means is a pressurized air tank.

3. The engine of claim **1** wherein the engine block is a Wankel-type rotary engine.

4. The engine of claim **3** is modified to gradually build up the walls at the forward to the direction of rotation end of the confined areas to alter the geometry of the internal open chamber.

5. The engine of claim **2** wherein the pressurized air tank is filled by a reciprocating compressor mechanically driven by an electrically powered gear reduction motor.

6. The engine of claim **1** wherein the engine starting means is compressed air.

7. The engine of claim **1** wherein the engine starting means is a 12 volt battery and a starter.

* * * * *

N. A. CHRISTENSEN.
MOTOR COMPRESSOR.
APPLICATION FILED MAR. 19, 1917.

1,369,618. **Patented Feb. 22, 1921.**

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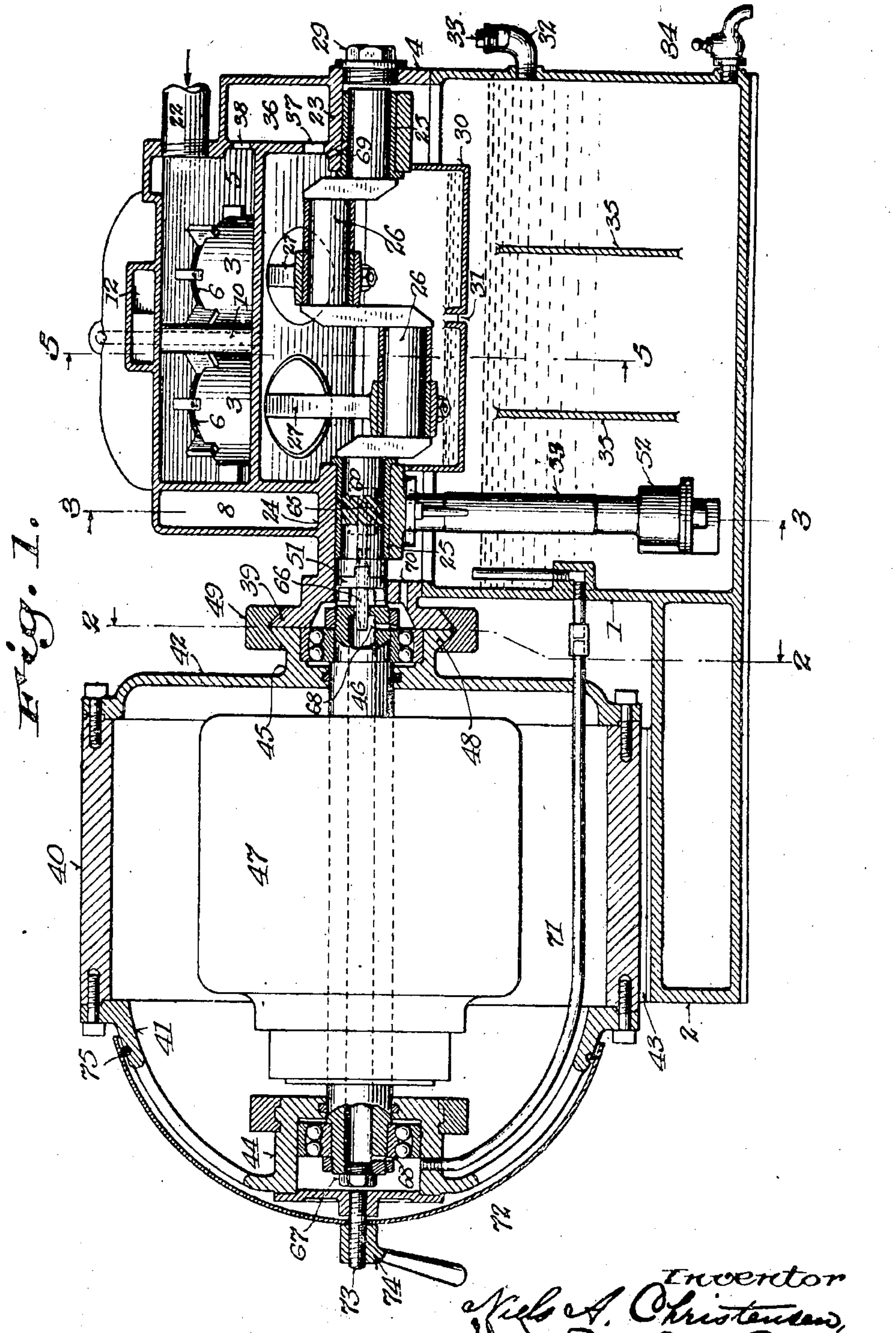

Fig. 1.

Inventor
Niels A. Christensen,
By Flanders Bottum Fawsett & Bottum
Attorneys.

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4 SHEETS—SHEET 2.

Fig. 3.

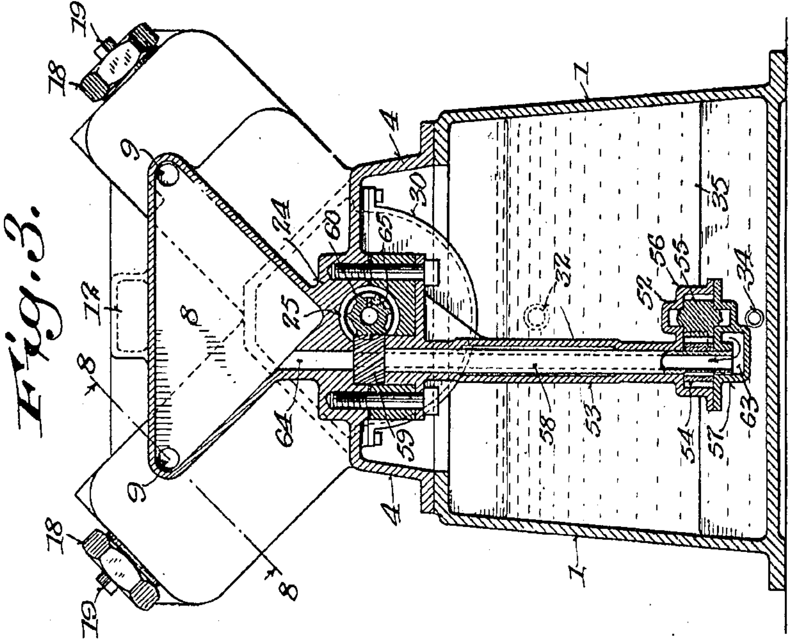
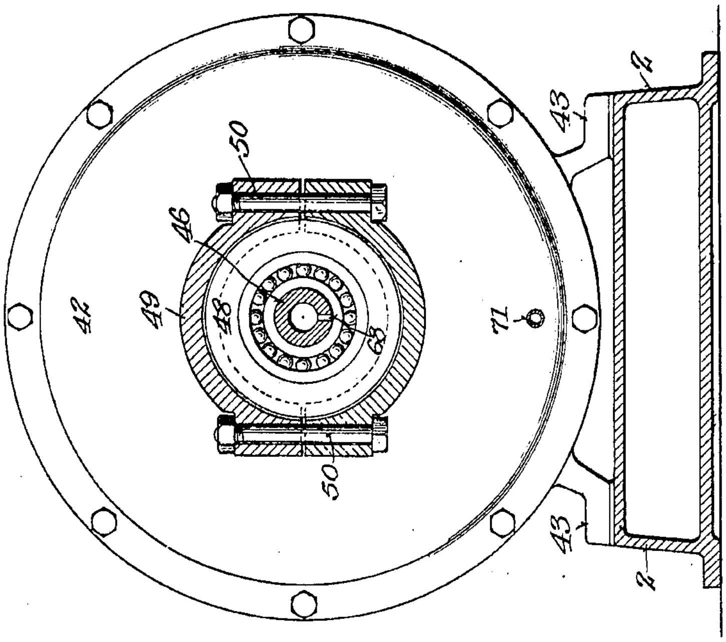


Fig. 2.



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4 SHEETS—SHEET 3.

Fig. 4.

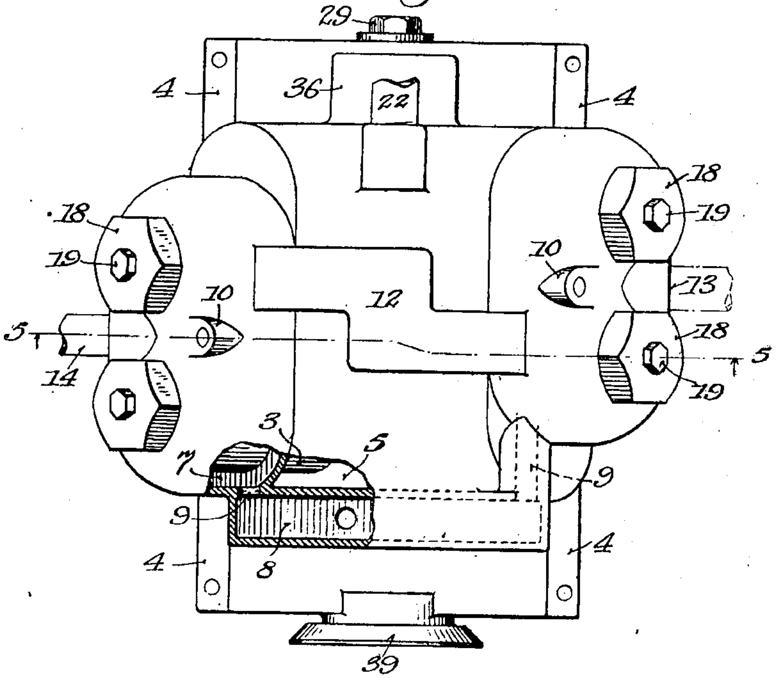
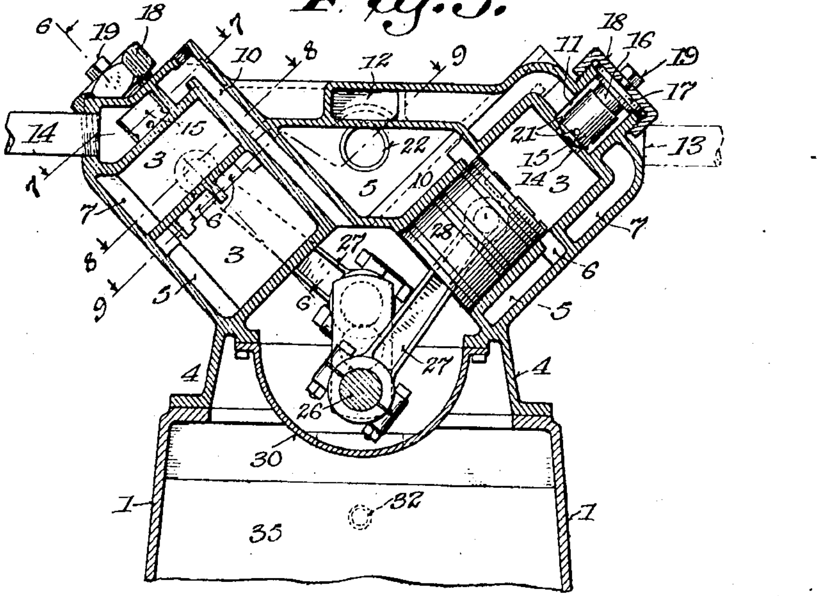


Fig. 5.



Inventor
Niels A. Christensen,
By Flanders Bottum Fawsett & Bottum
Attorneys.

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1,369,618.

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4 SHEETS—SHEET 4.

Fig. 6.

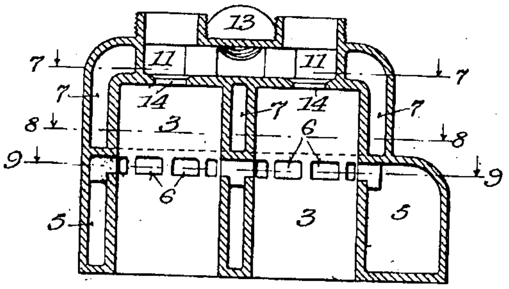


Fig. 10.

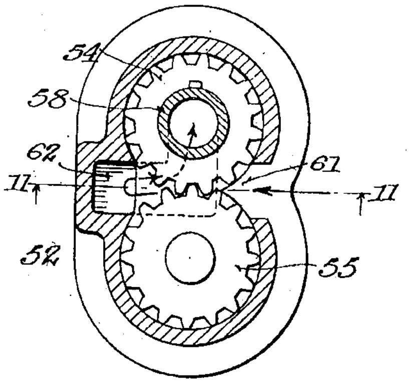


Fig. 7.

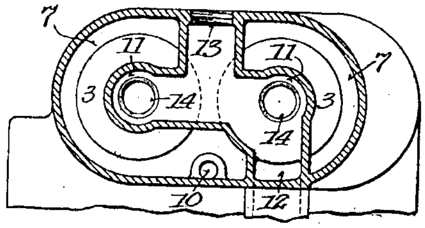


Fig. 11.

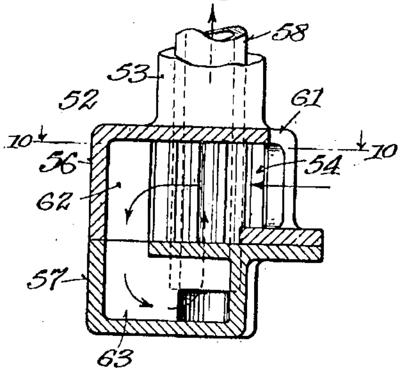


Fig. 8.

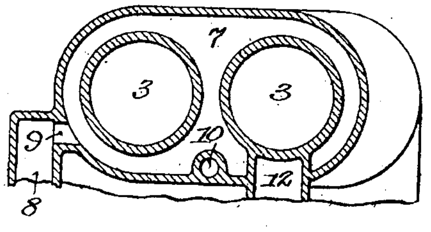


Fig. 12.

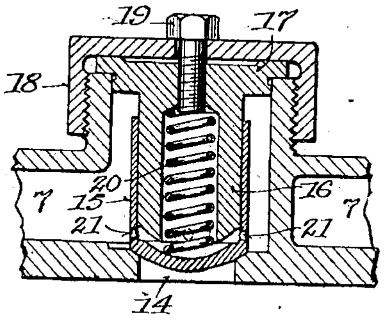
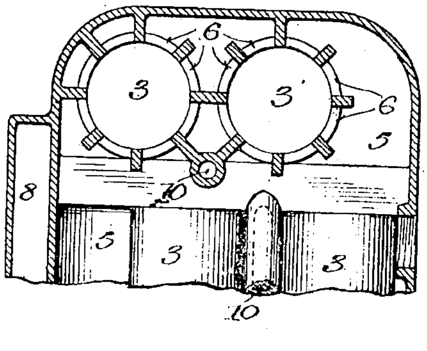


Fig. 9.



Inventor
Niels A. Christensen,
By Flanders Bottum Fawsett & Bottum
Attorneys.

UNITED STATES PATENT OFFICE.

NIELS A. CHRISTENSEN, OF MILWAUKEE, WISCONSIN.

MOTOR-COMPRESSOR.

1,369,618. Specification of Letters Patent. **Patented Feb. 22, 1921.**

Application filed March 19, 1917. Serial No. 155,675.

To all whom it may concern:

Be it known that I, Niels A. Christensen, a citizen of the United States, residing at Milwaukee, in the county of Milwaukee and State of Wisconsin, have invented certain new and useful Improvements in Motor-Compressors, of which the following is a specification, reference being had to the accompanying drawing, forming a part thereof.

This invention relates more particularly to a combined electric motor and air compressor forming a unitary structure in which the crank shaft of the compressor is arranged in axial alinement and directly connected with the armature shaft of the motor, and designed specially for air brake service on railway cars, although it is adapted to and may be used for other purposes.

The main objects of the invention are to produce self-contained compact apparatus which can be easily installed, will be reliable in operation and will require the least possible care and attention; to effectively protect the mechanism against dust, dirt, rain and snow, especially when the apparatus is installed and used in exposed positions, as underneath railway cars; to provide effective and adequate lubrication and cooling of the mechanism; and generally to simplify and improve the construction and operation of apparatus of this class.

The invention consists in the construction, arrangement and combination of parts as hereinafter particularly described and pointed out in the claims.

In the accompanying drawing like characters designate the same parts in the several figures.

Figure 1 is a vertical longitudinal section of a motor compressor embodying the invention: Figs. 2 and 3 are vertical cross sections on the lines 2—2 and 3—3 respectively, Fig. 1; Fig. 4 is a plan view of the compressor, a portion being broken away; Fig. 5 is a vertical cross section of the compressor on the line 5—5, Fig. 1; Fig. 6 is a longitudinal section on the line 6—6, Fig. 5, of a pair of compressor cylinders; Figs. 7, 8 and 9 are cross sections on the lines 7—7, 8—8 and 9—9 respectively, Fig. 5, the plane of the section of Fig. 8 being also indicated by the line 8—8, Fig. 3; Fig. 10 is an enlarged horizontal section on the line 10—10, Fig. 11, of the oil pump; Fig. 11 is a vertical section thereof on the line 11—11, Fig. 10; and Fig. 12 is an enlarged sectional view of one of the compressor discharge valves.

The apparatus comprises an oil reservoir 1, open and inwardly flanged at the top on which the compressor is mounted as hereinafter explained, and formed at one end with an extension 2, on which the motor is mounted and supported in proper relation to the compressor, as shown in Fig. 1. The compressor, which has two or more, in the present case four, cylinders 3, arranged in upwardly diverging pairs with their axes in planes intersecting the axis of the crank shaft, is cast integrally with a hollow outwardly flanged base 4, which is fitted and bolted to the inwardly flanged top of the reservoir 1, a sufficiently tight joint being formed by coating the contiguous faces of the castings with shellac. The cylinders, which open at their lower ends into a crank chamber formed in the base 4, are cast integrally with a large air inlet chamber 5, between and extending around the lower portions of the cylinders and communicating with inlet ports 6 about midway between the ends of the cylinders, as shown in Figs. 1, 5, 6 and 9. Above the inlet ports 6 the cylinders are cast with jackets forming oil circulating chambers or spaces 7, as shown in Figs. 5, 6, 7 and 8, and at one end of the compressor an oil chamber 8 is formed, which communicates through openings 9 with the oil chambers or spaces 7, as shown in Figs. 3 and 4. From the upper parts of the chambers or spaces 7, overflow passages 10, cast integrally with the cylinders, lead downwardly into the crank case, as shown in Figs. 5, 7, 8 and 9.

The cylinders are cast integrally at their upper closed ends with valve chambers 11, which in the present case are connnected in pairs on opposite sides of the compressor, as shown in Figs. 6 and 7, the two pairs of chambers being connected with each other by a passage 12 extending across and cast with the top of the chamber 5, as shown in Figs. 1, 4 and 5. Each pair of chambers 11 is formed with an outlet passage or opening 13, with which a discharge pipe 14 may be connected on either side of the compressor, as shown in Figs. 5, 6 and 7, the discharge opening which is not used, being closed with a plug.

The chambers 11 communicate with the cylinders 3 through ports 14, which are formed in the cylinder heads and are normally closed by spring seated disharge valves 15, as shown in Figs. 5 and 12. These valves, which are preferably made of cold drawn steel, are of cup shape, and are fitted on internal guides 16, formed at their upper ends with flanged heads 17, which are fitted in the openings into the valve chambers and are clamped and held in place therein by screw caps 18, threaded on upstanding necks or flanges around said openings, as shown in Figs. 5 and 12. The guides 16 are connected and removable with the caps 18 by means of screws 19, passing loosely through openings in the caps and threaded in the upper ends of the guides. The guides are formed with sockets to receive springs 20, by which the valves 15 are closed and normally held against their seats. The valves are formed, as shown in Fig. 12, with lateral openings 21 next to their closed ends, to permit air to pass freely into and out of the space between the lower ends of the guides and the closed ends of the valves, and thus allow the valves, which have a working fit on the guides, to open and close freely and promptly.

The construction and arrangement of the valves and associated parts as shown and described, prevents the deposit of carbon or foreign matter on the outside of the valves near their seats from interfering with their proper operation and removal, as when they are guided on the outside in the valve chambers or housings in the usual way. The springs by which the valves are closed are housed and protected and prevented in case of breakage from causing trouble.

The air inlet chamber 5 is formed at one end, as shown in Figs. 1 and 5, with an inlet opening with which a pipe 22 may be connected when the machine is used for air brake service on railway cars, for taking air from inside the cars or other places where it is free from dust and dirt.

Some distance above the joint between the oil reservoir 1 and the compressor base 4, the compressor casing is provided with crank shaft bearings 23 and 24, the upper halves of which are cast integrally with the casing and the lower halves of which are removably fastened thereto by bolts, as shown in Fig. 3. These bearings are preferably lined with flanged sleeves or bushings 25, of bronze or other suitable alloy or metal.

The crank shaft having in the present case two double cranks 26, directly connected by rods 27 with the pistons 28 above and on opposite sides thereof, is mounted in the bearings 23 and 24 entirely within the compressor casing and some distance above the top of the oil reservoir 1. Access is had to the bearing 23 and the journal of the crank shaft at that end of the compressor, through an opening formed in the base 4 of the compressor casing, and provided with a screw plug or removable closure 29, as shown in Figs. 1 and 4.

An oil pan 30, preferably of semi-cylindrical form corresponding with the circular path traversed by the cranks 26, is bolted or otherwise fastened to the compressor base 4 below the crank shaft, and is formed with an overflow opening 31, for maintaining at a predetermined level a small body of oil, into which the connecting rods 27 will dip at their lower ends when the compressor is in operation, and thereby splash the oil into the cylinders 3 above, for lubricating the pistons and other working parts of the compressor.

The reservoir 1 has at one end a funnel or spout 32, provided with a screw plug or cap 33, for filling it to a certain level some distance below the pan 30, as shown in Fig. 1. It also has a drain cock 34 at or near the bottom, for drawing off the oil, which should be occasionally renewed or replaced by fresh oil.

The reservoir is preferably formed, especially for air brake service on cars, with transverse baffle plates 35, as shown in Figs. 1 and 3 to prevent or counteract the surging of the oil above the top of the reservoir when the car on which the motor compressor is mounted is stopped and started.

At the end opposite the oil chamber 8 the compressor casing is formed with an air vent chamber 36, the lower part of which communicates through a small opening 37, with the crank chamber, and the upper part of which communicates through a smaller opening 38, with the air inlet chamber 5, as shown in Fig. 1, for relieving the crank chamber of back pressure and separating any oil from the air with which it may be carried into said chamber 36.

On account of the large volume of air contained in the upper part of the oil reservoir 1 and the base of the compressor, fluctuations of pressure in the crank case due to the normal action of the compressor pistons are comparatively small, and hence the pulsations of air from the crank chamber through the vent opening 37 into the chamber 36 will be light and insufficient to carry any considerable quantity of oil into the vent chamber 36. Whatever oil may be carried with the air into the chamber 36 will be precipitated therein and drained back through the vent opening 37, or an opening below it, into the reservoir 1.

The bearing 24 is extended and terminates beyond the base 4 of the compressor casing, in a beveled circular flange 39, as shown in Figs. 1 and 4.

The motor, which may be either of the direct or alternating current type, comprises a casing which may be conveniently made in three main sections, a substantially cylindrical middle section 40, and end plates or sections 41 and 42. The middle section 40, is formed with base flanges 43, which are fitted and bolted or otherwise fastened to the top of the extension 2 on the reservoir 1, as shown in Figs. 1 and 2.

The end sections 41 and 42 are formed or provided with central housings 44 and 45, for ball bearings in which the shaft 46 of the motor armature 47 is mounted. The housing 45 terminates in a beveled circular flange 48, corresponding with the flange 39 on the compressor casing, but beveled in the opposite direction. These flanges are accurately faced and fastened together with the crank shaft bearings 23 and 24, in axial alinement with the ball bearings of the armature shaft 46, by a clamping ring 49, formed with an internal V-groove fitting the beveled faces of the flanges 39 and 48. The ring 49 is made in two halves which are connected with each other and drawn tightly into place on the beveled flanges by bolts 50. The adjoining faces of the flanges 39 and 48 and clamping ring 49 are shellacked, and the joints between the ring sections are placed horizontally to form a tight joint and prevent leakage of oil between the end faces of the flanges.

The crank shaft of the compressor is connected with the armature shaft 46 of the motor by a self-adjusting coupling 51 of the Oldham type, as shown in Fig. 1, to compensate for misadjustment in the alinement of the shafts or their bearings, and to prevent binding of the shafts in their bearings.

The flanges 39 and 48 when assembled and clamped together by the ring 49, form a protecting housing for the shaft coupling 51.

An oil pump 52 is suspended in the oil reservoir 1 near the bottom thereof from the bearing 24, by a hanger 53, as shown in Figs. 1 and 3. The pump preferably consists, as shown in Figs. 3, 10 and 11, of two intermeshing gears 54 and 55, inclosed by and having bearings in a casing 56, which may be cast integrally with the hanger 53 and provided with a detachable closure or section 57. The gear 54 is fixed on the lower end of a tubular shaft 58 passing upwardly through the hanger 53, which is preferably of tubular form, and provided at its upper end with a spiral gear 59, housed in the bearing 24 and meshing with a spiral gear 60 formed on the crank shaft journal within said bearing. The gears 59 and 60 are proportioned to drive the shaft 58 at a reduced speed, say of about one revolution to two revolutions of the crank shaft. The pump casing 56 is formed with an inlet opening 61 at one side of the gears 54 and 55, and at the opposite side with an outlet port or passage 62, communicating through a registering passage 63 in the closure section 57 with the lower end of the tubular shaft 58. The upper end of the tubular shaft 58 communicates through a vertical passage 64 with the oil chamber 8 and with the chamber for the gears 59 and 60 in the bearing 24. The crank shaft journal in the bearing 24 has an axial bore communicating through a lateral opening 65 through the gear 60 with the interior of said bearing, as shown in Figs. 1 and 3. A tube or nozzle 66, threaded or otherwise fastened in said bore, extends axially therefrom loosely through the coupling member 51 into the adjacent end of the armature shaft 46, which is of tubular construction, as shown in Fig. 1. The bore of the shaft 46 at the end into which the nozzle 66 projects, is contracted and at the opposite end is closed by a screw plug 67, and lateral openings 68 lead from said bore into the ball bearing housings 44 and 45.

An oil hole 69 is formed through the upper part of the bearing 23 and its bushing, as shown in Fig. 1, for lubrication of the adjacent crank shaft journal by oil thrown by the connecting rods 27 from the pan 30 into the crank chamber.

An overflow opening 70 is made below the coupling 51 through the extension of the bearing 24 from the adjacent ball bearing housing, to conduct oil from the ball bearing housing 45 into the reservoir 1, and a pipe 71 leads from the housing 44 at the opposite end of the armature shaft into said reservoir.

The commutator end of the armature 47 is protected against dust, etc., by a shield 72, detachably fastened to the end plate or section 41 by a screw 73 and handle nut 74, a tight joint being made between the shield adjacent to its margin by a packing ring 75 held in a groove formed in the plate or section 41.

In the operation of the motor compressor, clean air entering the chamber 5 through the pipe 22 or an opening in the compressor casing, is drawn through the ports 6 when they are uncovered by the pistons 28, instantly filling the cylinders above the pistons. The ports 6 being arranged in series completely around the several cylinders, as clearly shown in Fig. 9, afford ample opening for the quick admission of air to the cylinders, and they are of such length and location that they will remain open during approximately one-third of the entire angular movement of the cranks 26, and for approximately one-fifth of the stroke or linear movement of the pistons.

The chamber 5 and the spaces around the cylinders with which it communicates being of comparatively large capacity, the inflow of air into said chamber will be substantially uniform and its discharge therefrom into the cylinders practically noiseless.

Upon the upward strokes of the pistons, the air is compressed in the upper ends of the cylinders, opening the valves 15 against the tension of the springs 20, and is discharged through the chambers 11 and connecting passages 12 and 13 into the pipe 14.

During the operation of the compressor, oil is elevated by the pump 52 from the lower part of the reservoir 1 into the chamber 8, from which it passes through the openings 9 into the spaces 7, around the upper ends of the cylinders 3 and valve chambers 11, overflowing through the passages 10 back into the crank case above the pan 30. From the pan 30, which is thus kept replenished to a certain level during the operation of the machine, the oil is thrown by the action of the connecting rods 27, upwardly into the cylinders, thereby thoroughly lubricating the pistons and their actuating connections with the crank shaft, surplus oil overflowing through the opening 31 back into the reservoir 1.

Sufficient oil is supplied by the splash from the pan 30 to thoroughly lubricate the bearing 23 through the hole 69 in the upper part thereof. The other crank shaft bearing 24 is lubricated with oil supplied by the pump 52 through the chamber in which the gears 59 and 60 are inclosed.

The bearings of the armature shaft 46 are lubricated by oil supplied from the pump through the opening 65 in the crank shaft, nozzle 66 and lateral openings 68 from the bore of the armature shaft, the surplus oil being returned from said bearings through the opening 70 and pipe 71 into the reservoir 1. Surplus oil from the crank shaft bearings 23 and 24 flows from the ends of said bearings directly back into the reservoir 1 or into the pan 30.

The constant circulation of fresh air through the chamber 5 and spaces communicating therewith around the lower parts of the cylinders 3, and the constant circulation of oil through the spaces 7 around the upper parts of the cylinders and the discharge valves when the machine is in operation, keeps the cylinders and pistons and the discharge valves cool and in proper working condition.

I claim:

1. In a machine of the class described, the combination with upwardly diverging compressor cylinders having inlet ports intermediate their ends, and a casing inclosing said cylinders and forming an air inlet chamber between and extending around them in communication with said ports and having an inlet communicating with the atmosphere.

2. In a machine of the class described, the combination of upwardly diverging compressor cylinders having inlet ports intermediate their ends, and a casing cast integrally with said cylinders and forming an air inlet chamber between and extending around them in communication with said ports and having an inlet communicating with the atmosphere, and a crank chamber into which the cylinders open at their lower ends.

3. In a machine of the class described, the combination of upwardly diverging compressor cylinders having inlet ports intermediate their ends and discharge ports in their upper heads, and a casing cast integrally with said cylinders and forming an air inlet chamber between and extending around them in communication with the inlet ports and having an inlet communicating with the atmosphere, a crank chamber into which the cylinders open at their lower ends, and interconnected valve chambers in communication with the discharge ports.

4. In a machine of the class described, the combination of a compressor cylinder, and a casing inclosing said cylinder and forming a crank chamber into which the cylinder opens at its lower end, and a separate oil chamber extending around the cylinder above the crank chamber and having an oil supply connection and an overflow opening into the crank chamber.

5. In a machine of the class described, the combination of upwardly diverging compressor cylinders, and a casing forming a closed crank chamber into which the cylinders open at their lower ends, a separate oil supply chamber extending above the crank chamber and oil circulating spaces around the cylinders connected by inlet openings with the supply chamber and by overflow passages with the crank chamber.

6. In a machine of the class described, the combination of an oil reservoir open at the top, a compressor having a casing formed with a crank chamber and base fitted to and closing the top of said reservoir and provided at the ends with crank shaft bearings, cylinders opening at their lower ends in said chamber and inclosed by said casing with oil circulating spaces which are connected by overflow passages with the crank chamber, pistons fitted in said cylinders, a crank shaft mounted in said bearings, rods connecting the crank shaft with the pistons, a pan located below

the crank shaft in position to catch oil from said overflow passages and having an overflow opening into the reservoir adapted to maintain oil in the pan at a certain level below which the lower ends of the connecting rods pass in the lower part of their circuit, and a pump adapted to elevate oil from the reservoir into the circulating spaces around the cylinders.

7. In a machine of the class described, the combination of compressor cylinders having inlet ports intermediate their ends, and a casing forming a crank chamber into which the cylinders open at their lower ends, an air inlet chamber extending around the lower parts of the cylinders in communication with the inlet ports, and oil circulating spaces extending around the upper parts of the cylinders and having an oil supply connection and overflow openings into the crank chamber.

8. In a machine of the class described, the combination of upwardly diverging compressor cylinders closed at their upper ends and provided with discharge ports and valves, and a casing forming a crank chamber into which the cylinders open at their lower ends, an air inlet chamber between and extending around the lower parts of the cylinders, intercommunicating chambers for the discharge ports and valves, and oil circulating spaces extending around the upper parts of the cylinders and discharge valve chambers and having overflow openings into the crank chamber.

9. In a machine of the class described, the combination of an oil reservoir open at the top, upwardly diverging compressor cylinders having inlet ports intermediate their ends and discharge ports in their upper ends, a casing formed with a crank chamber and base fitted to and closing the top of the reservoir, an air inlet chamber between and around the lower parts of the cylinders in communication with their inlet ports, an oil chamber, and circulating spaces around the upper parts of the cylinders having inlet openings from said oil chamber and overflow openings into the crank chamber; and a pump for elevating oil from the reservoir into said oil chamber.

10. In a machine of the class described, the combination of an oil reservoir open at the top, upwardly diverging compressor cylinders having inlet ports intermediate their ends and discharge ports in their upper ends; a casing formed with a crank chamber and base into which the cylinders open at their lower ends and which is fitted to and closes the top of the reservoir, an air inlet chamber between and around the lower parts of the cylinders in communication with said inlet ports, an oil chamber, and circulating spaces around the upper parts of the cylinders having inlet openings from said oil chamber and overflow openings into the crank chamber; a pump for elevating oil from the reservoir into said oil chamber; a crank shaft mounted in bearings within said casing above said reservoir, pistons fitted in said cylinders, rods directly connecting the crank shaft with the pistons, a pan located below and in the path of the lower ends of the connecting rods in position to catch oil from said overflow openings and having an overflow opening adapted to maintain oil at a certain level in the pan; and a pump for elevating oil from the reservoir into said oil chamber.

11. In a machine of the class described, the combination of compressor cylinders having inlet ports intermediate their ends, an air chamber communicating with said inlet ports and having an inlet opening in communication with the atmosphere, a closed crank chamber, and a vent chamber communicating through an opening with the crank chamber and through another opening with said air chamber.

12. In a machine of the class described, the combination of an oil reservoir having an extension at one end, a compressor having a casing mounted upon and closing the top of said reservoir and provided at the ends with bearings, a crank shaft mounted in said bearings and having an oil passage through one of its journals, a motor having a casing mounted on the extension of the oil reservoir and having bearings in substantial axial alinement with said crank-shaft bearings, a tubular motor shaft mounted in the bearings of said motor casing and coupled end to end with the crank-shaft journal having the oil passage, a pump for elevating oil from said reservoir into the bearing of the crank-shaft journal having the oil passage, and return oil conduits leading from the motor shaft bearings into said reservoir.

13. In a machine of the class described, the combination of a supporting member, compressor and motor casings mounted on said member and provided with alined shaft bearings and with beveled circular flanges coaxial with adjacent bearings, a contractible clamping ring having an internal V-groove fitting over said flanges and binding them together, compressor and motor shafts mounted in said bearings, and a self-adjusting coupling connecting said shafts end to end, the flanges forming a housing for the shaft coupling.

14. In a machine of the class described, the combination of a supporting member and oil reservoir, compressor and motor casings mounted on said supporting member and oil reservoir and provided with alined shaft bearings and at adjoining ends with corresponding beveled circular coupling flanges coaxial with the adjacent bearings, a con-

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tractible clamping ring having an internal V-groove fitting over said flanges and binding them together, a crank shaft mounted in the bearings of the compressor casing and having an axial oil passage in the end next to the motor, a tubular motor shaft mounted in the bearings of the motor casing and having a contracted opening at one end in alinement with the oil passage in the crank shaft, a self-adjusting coupling connecting said shafts end to end, a nozzle extending from the oil passage in the crank shaft through said coupling into the motor shaft at the end with the contracted opening, a pump for elevating oil from the reservoir into the passage in the crank shaft, and return oil conduits from the motor shaft bearings into the reservoir.

In witness whereof I hereto affix my signature.

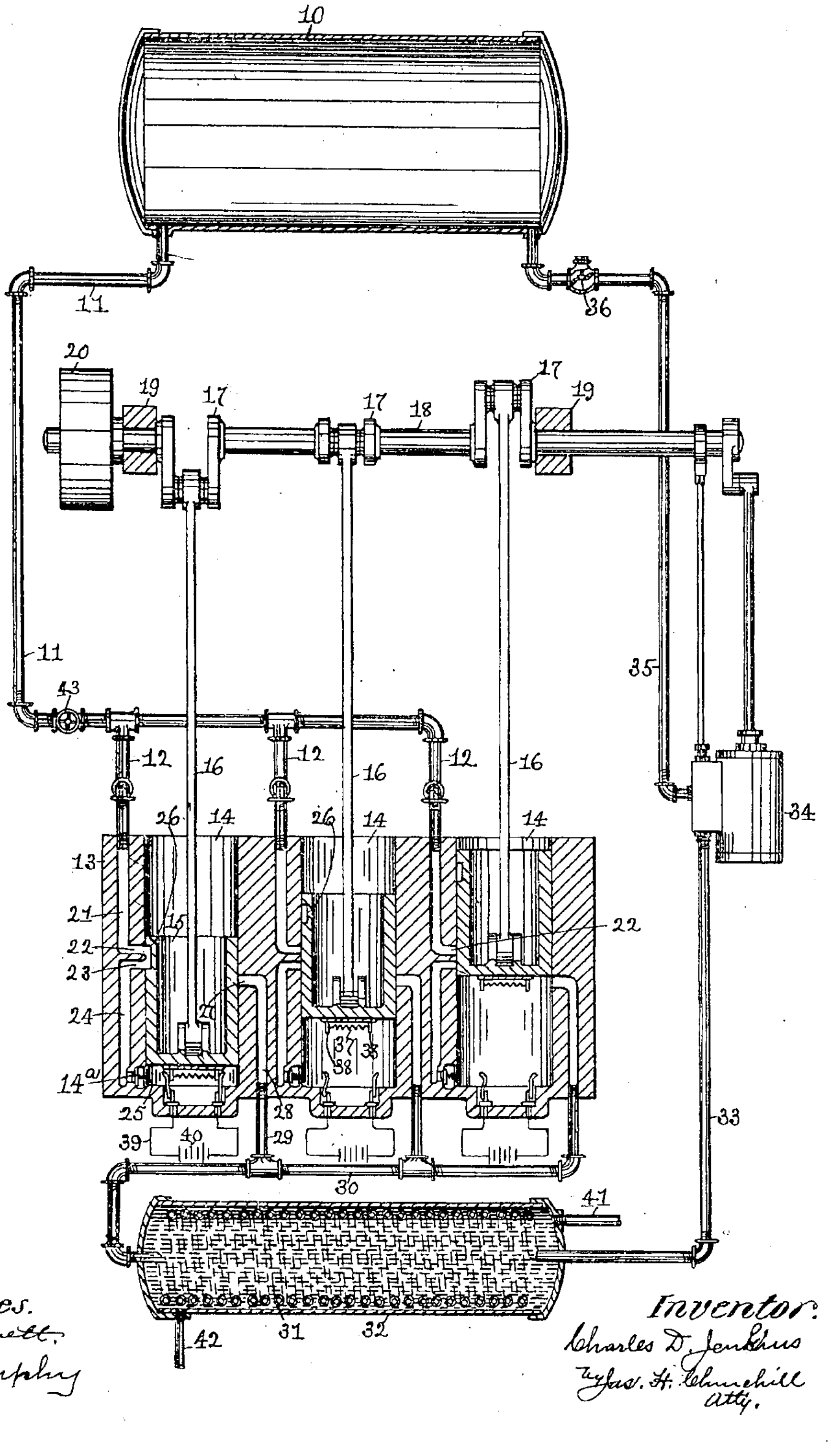
NIELS A. CHRISTENSEN.

No. 868,441. PATENTED OCT. 15, 1907.

C. D. JENKINS.

COMPRESSED AIR MOTOR.

APPLICATION FILED MAY 6, 1907.



Witnesses.
C. H. Garrett.
J. Murphy

Inventor:
Charles D. Jenkins
by Jas. H. Churchill
Atty.

NORRIS PETERS, INC., LITHO. WASHINGTON, D. C.

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UNITED STATES PATENT OFFICE.

NIELS A. CHRISTENSEN, OF MILWAUKEE, WISCONSIN.

MOTOR-COMPRESSOR.

1,369,618. Specification of Letters Patent. Patented Feb. 22, 1921.

Application filed March 19, 1917. Serial No. 155,675.

To all whom it may concern:

Be it known that I, Niels A. Christensen, a citizen of the United States, residing at Milwaukee, in the county of Milwaukee and State of Wisconsin, have invented certain new and useful Improvements in Motor-Compressors, of which the following is a specification, reference being had to the accompanying drawing, forming a part thereof.

This invention relates more particularly to a combined electric motor and air compressor forming a unitary structure in which the crank shaft of the compressor is arranged in axial alinement and directly connected with the armature shaft of the motor, and designed specially for air brake service on railway cars, although it is adapted to and may be used for other purposes.

The main objects of the invention are to produce self-contained compact apparatus which can be easily installed, will be reliable in operation and will require the least possible care and attention; to effectively protect the mechanism against dust, dirt, rain and snow, especially when the apparatus is installed and used in exposed positions, as underneath railway cars; to provide effective and adequate lubrication and cooling of the mechanism; and generally to simplify and improve the construction and operation of apparatus of this class.

The invention consists in the construction, arrangement and combination of parts as hereinafter particularly described and pointed out in the claims.

In the accompanying drawing like characters designate the same parts in the several figures.

Figure 1 is a vertical longitudinal section of a motor compressor embodying the invention; Figs. 2 and 3 are vertical cross sections on the lines 2—2 and 3—3 respectively, Fig. 1; Fig. 4 is a plan view of the compressor, a portion being broken away; Fig. 5 is a vertical cross section of the compressor on the line 5—5, Fig. 1; Fig. 6 is a longitudinal section on the line 6—6, Fig. 5, of a pair of compressor cylinders; Figs. 7, 8 and 9 are cross sections on the lines 7—7, 8—8 and 9—9 respectively, Fig. 5, the plane of the section of Fig. 8 being also indicated by the line 8—8, Fig. 3; Fig. 10 is an enlarged horizontal section on the line 10—10, Fig. 11, of the oil pump; Fig. 11 is a vertical section thereof on the line 11—11, Fig. 10; and Fig. 12 is an enlarged sectional view of one of the compressor discharge valves.

The apparatus comprises an oil reservoir 1, open and inwardly flanged at the top on which the compressor is mounted as hereinafter explained, and formed at one end with an extension 2, on which the motor is mounted and supported in proper relation to the compressor, as shown in Fig. 1. The compressor, which has two or more, in the present case four, cylinders 3, arranged in upwardly diverging pairs with their axes in planes intersecting the axis of the crank shaft, is cast integrally with a hollow outwardly flanged base 4, which is fitted and bolted to the inwardly flanged top of the reservoir 1, a sufficiently tight joint being formed by coating the contiguous faces of the castings with shellac. The cylinders, which open at their lower ends into a crank chamber formed in the base 4, are cast integrally with a large air inlet chamber 5, between and extending around the lower portions of the cylinders and communicating with inlet ports 6 about midway between the ends of the cylinders, as shown in Figs. 1, 5, 6 and 9. Above the inlet ports 6 the cylinders are cast with jackets forming oil circulating chambers or spaces 7, as shown in Figs. 5, 6, 7 and 8, and at one end of the compressor an oil chamber 8 is formed, which communicates through openings 9 with the oil chambers or spaces 7, as shown in Figs. 3 and 4. From the upper parts of the chambers or spaces 7, overflow passages 10, cast integrally with the cylinders, lead downwardly into the crank case, as shown in Figs. 5, 7, 8 and 9.

The cylinders are cast integrally at their upper closed ends with valve chambers 11, which in the present case are connnected in pairs on opposite sides of the compressor, as

UNITED STATES PATENT OFFICE.

CHARLES D. JENKINS, OF BOSTON, MASSACHUSETTS.

COMPRESSED-AIR MOTOR.

No. 868,441. Specification of Letters Patent. **Patented Oct. 15, 1907.**

Application filed May 6, 1907. Serial No. 372,117.

To all whom it may concern:

Be it known that I, Charles D. Jenkins, a citizen of the United States, residing in Boston, in the county of Suffolk and State of Massachusetts, have invented an Improvement in Compressed-Air Motors, of which the following description, in connection with the accompanying drawings, is a specification, like letters on the drawings representing like parts.

This invention relates to motors to be operated by compressed-air and has for its object the production of a motor in which heat is applied to the compressed-air at the point it is to act upon the piston thereby greatly increasing the efficiency thereof.

It consists in certain novel features of construction and arrangement of parts which will be understood readily by reference to the description of the drawings and to the claims to be hereinafter given.

The drawings represent a diagrammatic view of the various features which constitute this invention.

In the drawing 10 is a suitable tank or reservoir for the storage of compressed-air under suitable pressure, said tank being connected by a pipe 11 and branch pipes 12 to the cylinder casting 13, which is provided with a plurality of cylinders 14. In each cylinder is mounted a piston 15 connected by a piston rod 16 to a crank 17 on the shaft 18 mounted in bearings 19 and provided with a driving wheel 20, from which power may be transmitted to any desired point.

In the cylinder casting 13 are passages 21 connecting with the branch pipes 12 at one end and with the ports 22 at the other end communicating with the cylinders 14. Adjacent to the port 22 is another port 23 communicating by the passage 24 with a port 25 in the bottom of the cylinder 14. Each piston 15 is provided with a passage 26 so located that when the piston is at the extreme inner end of its movement, it will communicate with both the ports 22 and 23 and permit the passage of compressed-air through the pipes 12, passages 21 and 24 and ports 25 to the cylinder 14 back of the piston 15.

The piston 15 serves to close the ports 22, 23 and thereby prevent the passage of the compressed-air to the cylinder except when the piston is in the proper position to be acted upon by the expansion of the compressed-air. A check valve 14ª prevents the exit from the cylinder of the compressed air admitted thereto during the expansion thereof. An exhaust port 27 also communicates with each cylinder 14 and connects the same by passages 28 and pipes 29 and 30 with a coil 31 located in a tank 32, the opposite end of said coil being connected by a pipe 33 to a pump 34 arranged to pump the exhaust air through the pipe 35 into the main reservoir, a check valve 36 preventing the return thereof.

Each piston is provided upon its inner end with an electric coil 37 and two contact points 38, which, when the piston is at the inner end or chamber-forming portion of its stroke, make an electric connection with the circuit 39 in which is a battery or other generator of electricity, 40. When the circuit is made, by the movement of the piston 15, a current of electricity passes through the coil 37 or a similar heating device and causes an intense heat, which, acting upon the compressed-air being at this time admitted to the cylinder, greatly expands the same and increases its efficiency. This forms a very important feature of the invention as it provides a very convenient means for increasing the power of a compressed-air motor without the necessity of increasing the pressure in the storage tank. The tank 32 is used to cool the exhaust air passing from the cylinders 14, it being provided with an inlet pipe 41 and outlet pipe 42, which permits water or other cooling liquid to be admitted as desired and by contact with the coil 31 to cool the air passing through the same before it is pumped back into the reservoir 10.

The operation of the invention is as follows:—The tank 10 is supplied with compressed-air from any convenient source and under any desired pressure. When it is desired to start the engine, the valve 43 is opened and the compressed-air is allowed to pass through the pipes 12 to the ports 21. By turning the driving wheel by hand the air is admitted to the cylinders 14 and is then expanded by the heat in coils 37, so that the pistons will be driven to the opposite ends of their strokes. As soon as each piston begins to move, the heat is shut off and remains shut off until the piston again reaches the bottom of the cylinder when the operation is repeated. The cranks 17 are placed at equal distances about the shaft 18 so that the motor will be perfectly balanced. As soon as the motor has made a few revolutions by the aid of the operator it will continue to operate until the valve 43 is again closed. The exhaust from the engine is thoroughly cooled in the tank 32, thereby lowering the pressure thereof before being pumped back into the storage reservoir 10.

Claims.

1. The combination with a source of air under pressure, of an air engine comprising a cylinder and a piston reciprocating in said cylinder and coöperating therewith to form a substantially small chamber when the piston is at the end of its stroke in one direction, means to admit compressed-air into said chamber, an electric conductor located in said chamber when the piston is at the end of the stroke on which said chamber is formed and capable of being highly heated, an electric circuit in which said conductor is included when the piston is at the end of its chamber-forming stroke, and a circuit controller for said circuit operated to close the same and highly heat the con-

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ductor when the piston is at or near the end of its chamber-forming stroke to thereby expand the compresed-air and propel the piston, substantially as described.

2. The combination with a cylinder and a piston reciprocating therein to form a substantially small chamber when the piston is at the end of its stroke in one direction, an electric conductor movable with said piston, an electric circuit having terminals extended within said cylinder and coöperating with said electric conductor to include the latter in a closed circuit and thereby highly heat the conductor when the piston is at the end of its stroke in one direction, substantially as described.

In testimony whereof, I have signed my name to this specification in the presence of two subscribing witnesses.

CHARLES D. JENKINS.

Witnesses:

JAS. H. CHURCHILL,
J. MURPHY.

J. D. KNEEDLER.
HEAT AND POWER PRODUCING APPARATUS,
APPLICATION FILED MAR. 3, 1917.

1,297,363. Patented Mar. 18, 1919.

Fig. 1.

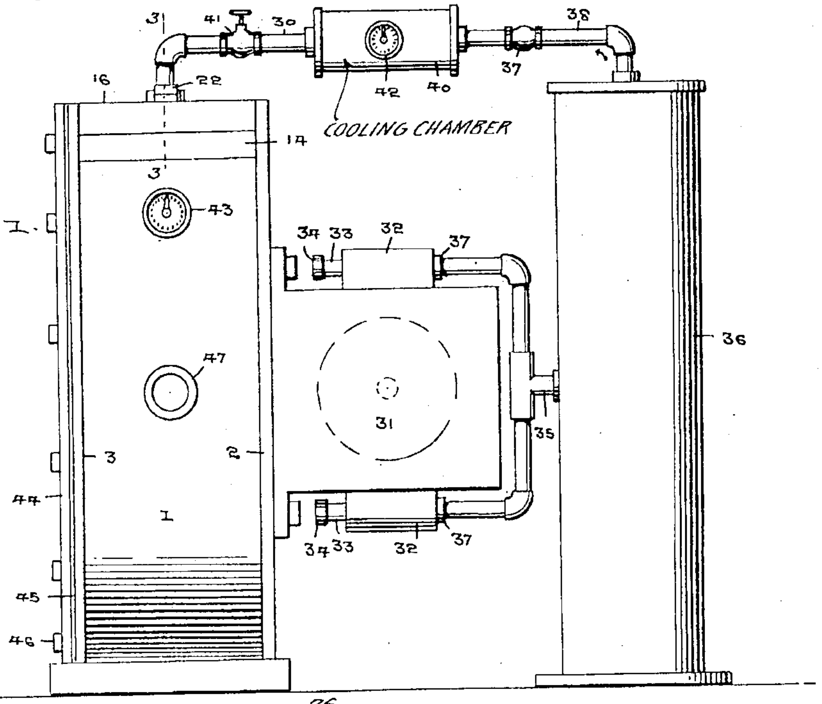


Fig. 2.

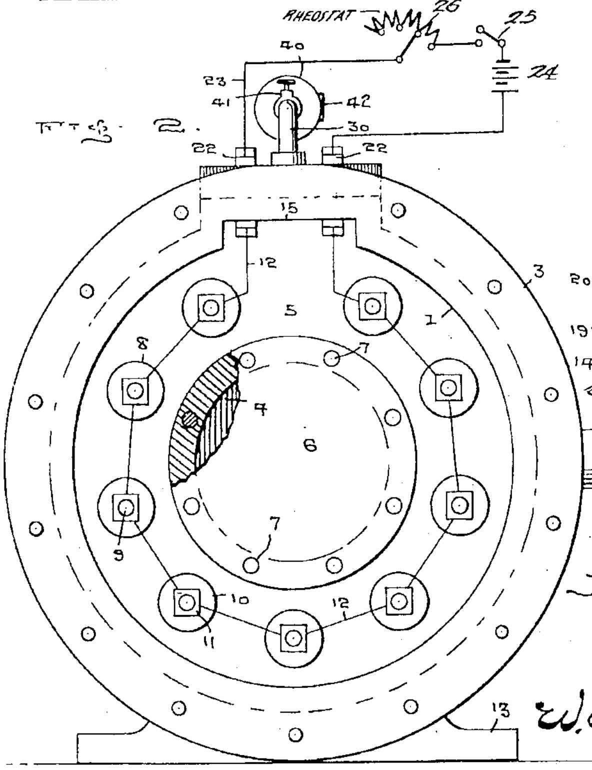
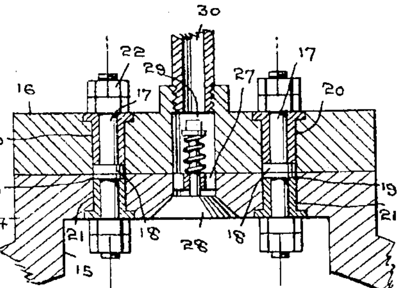


Fig. 3.



Inventor
John D. Kneedler

By
W. T. FitzGerald & Co.
Attorneys

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

UNITED STATES PATENT OFFICE.

JOHN D. KNEEDLER, OF SIOUX CITY, IOWA, ASSIGNOR OF ONE-HALF TO BUEL COUCH, OF SIOUX CITY, IOWA.

HEAT AND POWER PRODUCING APPARATUS.

1,297,363. Specification of Letters Patent. Patented Mar. 18, 1919.

Application filed March 3, 1917. Serial No. 152,397.

To all whom it may concern:

Be it known that I, John D. Kneedler, a citizen of the United States, residing at Sioux City, in the county of Woodbury and State of Iowa, have invented certain new and useful Improvements in Heat and Power Producing Apparatus; and I do hereby declare the following to be a full, clear, and exact description of the invention, such as will enable others skilled in the art to which it appertains to make and use the same.

This invention relates to a heat and power producing apparatus and has for its principal object to provide a device of this character whereby any desired amount of heat and power may be produced and subsequently utilized, as desired, for heating purposes and for power purposes, such as driving engines and the like.

Another object of the invention is to introduce compressed air into an expansion chamber and to provide electrical means for expanding the compressed air within the expansion chamber.

A further object is to provide a series of heating coils designed to be arranged within the expansion chamber, suitable electrical means being connected in circuit with these coils, whereby the compressed air within the expansion chamber may be expanded to any desired degree of pressure.

A still further object of the invention is to pass the compressed air through a cooling or condensation chamber before it is introduced into the expansion chamber.

With these and other objects in view, as will appear as the description proceeds, the invention comprises various novel features of construction, combination and arrangement of parts as will be more fully described hereinafter and set forth with particularity in the appended claims.

Referring to the drawings,

Figure 1 is a side elevation of my improved heat and power producing apparatus.

Fig. 2 is a side elevation of the expansion chamber with the cover plate removed, and

Fig. 3 is a vertical transverse sectional view taken on the line 3—3 of Fig. 1.

Similar characters of reference are used to denote like parts throughout the following description and the accompanying drawings.

Referring more particularly to the drawings, the reference numeral 1 indicates an expansion chamber, which in this instance is of circular formation and is provided at its opposite side edges with circumferential flanges 2 and 3, respectively.

Arranged concentrically within the expansion chamber 1 is a sleeve 4 that is securely attached to the rear wall 5 of the expansion chamber and has its opposite end closed by a cover plate 6, this plate being secured to the sleeve by screws 7.

Positioned within the expansion chamber between the sleeve 4 and the inner wall of the chamber 1 are a plurality of heat radiating coils 8, and each is shown to consist of a stud 9 that is threaded into the rear wall 5, a suitable insulating sleeve 10 being mounted thereon and securely held in position by retaining nuts 11. A conductor wire 12 is successively wound around each of the insulating sleeves 10 to produce a series of heating coils by which any desired amount of heat may be produced within the expansion chamber.

As shown, the expansion chamber is provided with a suitable supporting base 13 and is provided at the top with a head portion 14 that is provided with a transversely extending recess 15. A head block 16 is mounted upon the head portion 14 between the side flanges 2 and 3 and is securely held in position through the medium of a pair of studs 17, each of which is provided intermediate its ends with a collar 18 that is designed to bear upon an insulating washer 19. Each of the studs 17 is positioned within insulating sleeves 20 and 21 that are positioned within the head block and the head portion respectively. Each end of each stud is provided with a pair of nuts 22 whereby the terminal ends of the conductor wires 12 and 23 may be connected thereto. The conductor wire 23 leads to a suitable source of current 24 and is designed to be controlled by a suitable switch 25 interposed between the battery and the heating coils. A variable current producing device or rheostat 26 is also connected in circuit with the controlling switch, whereby the heat radiating coils may be caused to radiate any desired amount of heat.

The head portion 14 of the expansion chamber is provided with an air inlet opening 27 in which is arranged a check valve 28 that is designed to open inwardly of the expansion chamber. This inlet opening 27 registers with a similar opening 29 in the head block 16, and threadedly connected to the head block is an air inlet pipe 30 by which air can be conveyed from a suitable source into the expansion chamber.

Mounted upon the outside of the rear wall 5 is a double acting air compressor 31 that is provided on its opposite sides with controlling valves 32, each of which has connected to it an inlet pipe 33 provided with an inwardly opening check valve 34. Each of the valves 32 is connected to a conduit pipe 35 which in turn is connected to an air tank 36, check valves 37 being provided at the opposite end of each valve 32 to prevent air that has been once pumped into the air tank from escaping.

The air tank 36 has connected to it a conveyer pipe 38 in which is arranged a check valve 39, this pipe being connected to an air cooling and condensation chamber 40, which in turn is connected to the expansion chamber through the medium of the conduit pipe 30, and arranged within this pipe 30 is a suitable controlling valve 41. The air cooling chamber 40 is provided with a pressure gage 42 whereby the pressure of the air within the tank 36 may be readily seen at all times.

The expansion chamber is also provided with a pressure gage 43 by which the pressure of the air within the expansion chamber may be seen.

Arranged over the open side of the expansion chamber is a cover plate 44 that rests upon a suitable gasket 45 and is securely held in position by bolts 46, this cover plate forming an air-tight connection between the inner sleeve 4 and the outer wall of the chamber.

From the foregoing description, it will be apparent that air is first compressed within the air tank 36 and then conveyed through the cooling chamber 40 to the expansion chamber where it is expanded through the medium of the electrical heating coils to any desired degree, these coils not only expanding the compressed air to a greater expansible force but also heating it the desired amount. As soon as the air has been heated and expanded to the desired degree of heat and pressure, it is exhausted from the expansion chamber through an exhaust port 47 to be subsequently used for driving an engine or for other power purposes, and also to be used for any desired heating purposes.

In the operation of the apparatus the air is unavoidably heated and expanded as it is pumped into the tank 36 by the action of the compressor. In order to restore the expansive force to the air prior to entering the expansion chamber, it is found desirable and necessary to cool the air to substantially a freezing point. When the cold air enters the expansion chamber and strikes the heating coils, the air is heated and expanded. For instance if the rheostat 26 was operated so that the coils would become red hot and cold air were admitted to the expansion chamber under pressure, it would obviously be expanded very quickly to an increased pressure.

What I claim as new is:—

1. A heat and power producing apparatus of the class described comprising an expansion chamber, a core mounted within the expansion chamber, variable heating means positioned around and within said expansion chamber, means for supplying compressed air to said expansion chamber for contact with said heating means for the purpose set forth, and means for refrigerating said compressed air prior to its admission to said expansion chamber.

2. A heat and power producing apparatus of the class described comprising an expansion chamber, a compressed air storage tank, means carried by said expansion chamber for compressing the air within said storage tank, means connecting said compressed air storage tank with said expansion chamber, refrigerating means positioned in said connecting means whereby the compressed air will be cooled prior to its admission into said expansion chamber, and variable heating means positioned within said expansion chamber for expanding the cooled air introduced into the expansion chamber.

3. In a heat and power producing apparatus of the class described, a circular expansion chamber having inlet and outlet ports, a check valve arranged in said inlet port, a hollow core arranged centrally within said expansion chamber to provide a circular space therein, and electrical heating means positioned in said space around said core for expanding the air introduced into the expansion chamber.

In testimony whereof I have signed my name to this specification in the presence of two subscribing witnesses.

JOHN D. KNEEDLER.

Witnesses:
EARL E. SNELL,
E. G. BROWN.

Copies of this patent may be obtained for five cents each, by addressing the "Commissioner of Patents, Washington, D. C."

May 2, 1961 C. L. McCLINTOCK **2,982,261**

AIR ENGINE

Filed July 7, 1958 2 Sheets-Sheet 1

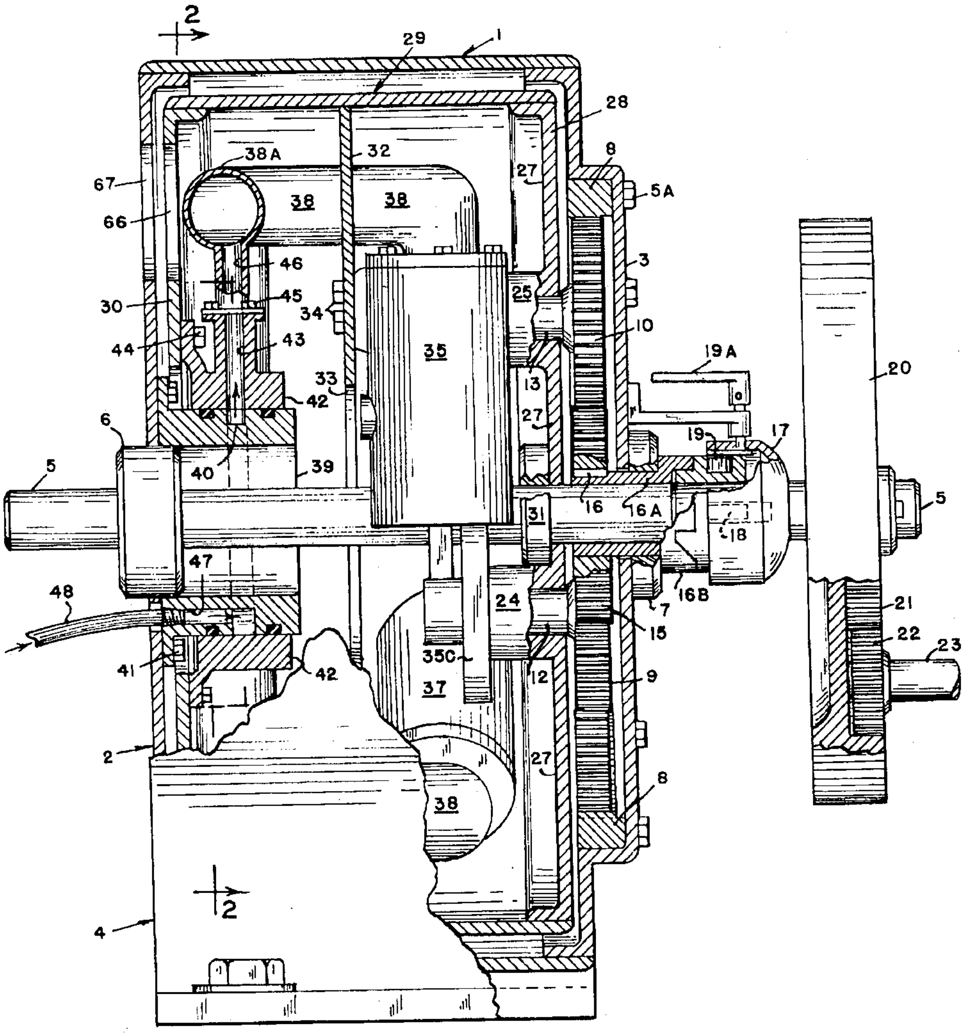


FIG.1

CLEO L. McCLINTOCK
INVENTOR.

BY *James L Givnan* ATT'Y

May 2, 1961 C. L. McCLINTOCK **2,982,261**

AIR ENGINE

Filed July 7, 1958

2 Sheets-Sheet 2

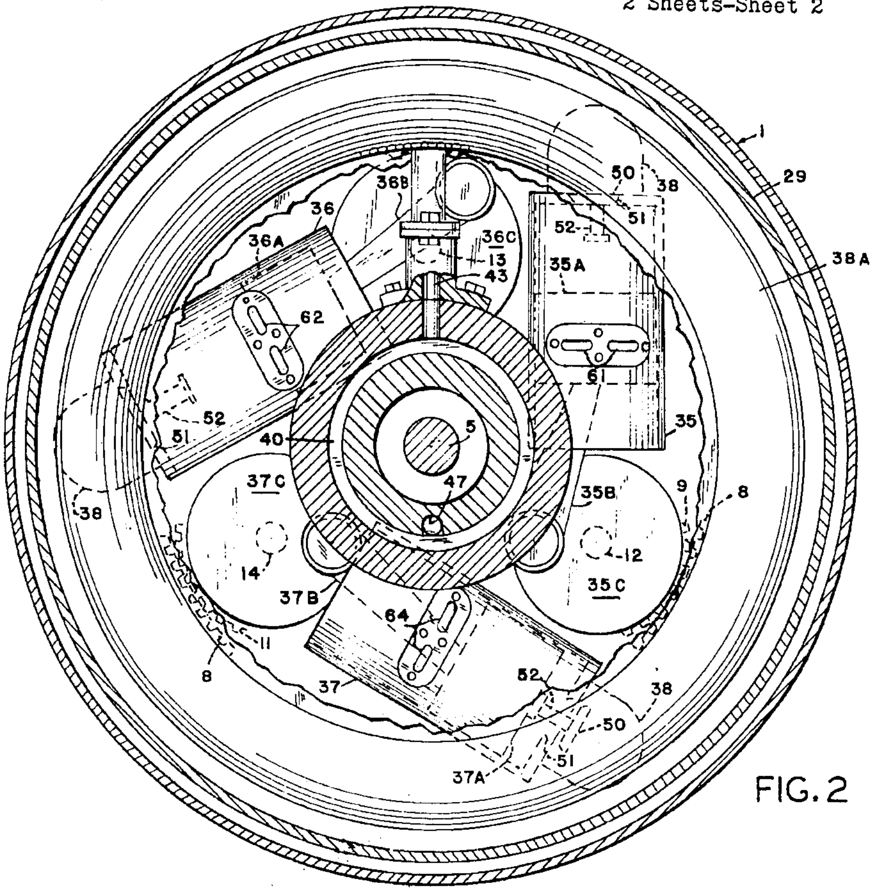


FIG. 2

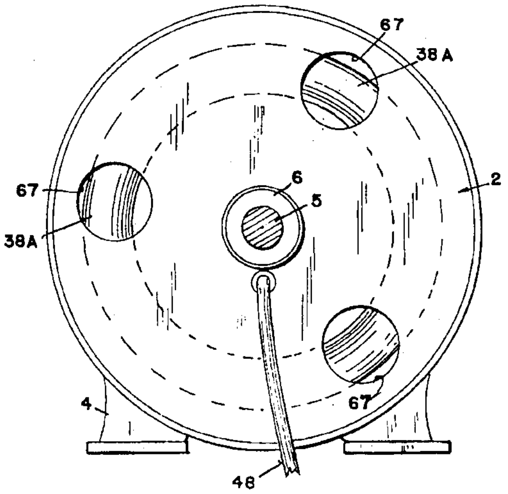


FIG. 3

CLEO L. McCLINTOCK
INVENTOR.

BY James L. Givnan ATT'Y

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United States Patent Office

2,982,261

Patented May 2, 1961

2,982,261

AIR ENGINE

Cleo L. McClintock, Portland, Oreg., assignor to
Edward M. Nelson, Colton, Oreg.

Filed July 7, 1958, Ser. No. 746,757

1 Claim. (Cl. 121—58)

This invention relates to improvements in engines and more particularly to an engine operated by fluid pressure and the expansion forces thereof at operating temperatures of the engine.

The objects and advantages of the invention will become apparent as the description proceeds and that the invention consists essentially in the novel combination and arrangement of parts hereinafter described in detail and illustrated in the accompanying drawings.

In the accompanying drawings:

Figure 1 is a side view of an engine made in accordance with my invention and with fragments broken away and some parts in section for convenience of illustration.

Figure 2 is a sectional end view taken approximately along the line 2—2 of Figure 1.

Figure 3 is a view on a reduced scale of the left end of Figure 1.

Referring now more particularly to the drawings:

In the preferred embodiment of the features of my invention as here shown, reference numeral **1** indicates a stationary cylindrical housing closed at both of its ends by end walls **2** and **3** and provided with suitable supporting legs indicated generally at **4**. An engine shaft **5** extends entirely through the housing **1** and is journaled in anti-friction bearings **6** and **7** secured to the end walls **2** and **3** respectively of the housing **1**. Secured as at **5A** to the end wall **3** is an internal ring gear **8** enmeshed at all times with three planet gears **9**, **10** and **11**, secured to one end of shafts **12**, **13** and **14**, respectively. The planet gears are enmeshed at all times with a sun gear **15** keyed or otherwise secured as at **16** to the inner end of a sleeve **16A** freely rotatable about the engine shaft **5**. The opposite or outer end of the sleeve terminates in a clutch element **16B** cooperating with a manually disengageable companion clutch element **17** slidably splined as at **18** to the engine shaft **6** and operable into and out of engagement with the clutch element **16B** by any approved type of actuating mechanism such as the rollers **19** and handle **19A**. The outer end of the engine shaft is provided with a flywheel **20**. The inner periphery of the flywheel is cast integral with or provided with an internal ring gear **21** meshing at all times with a driving gear **22** secured to one end of a shaft **23** of a starting motor (not shown).

The shafts **12**, **13** and **14** of the planet gears are rotatably mounted in bearings respectively **24**, **25** and **26**, formed in a carrier **27** in the form of a disc which provides one end wall **28** of a cylindrical housing **29** disposed within the main housing **1** closed by an opposing end wall **30** and freely rotatable about the engine shaft **5** by means of anti-friction bearings **31**.

An intermediate wall **32** is secured within the cylindrical housing **29** and is provided with a central concentric opening **33**. Securely mounted as at **34** to the wall **32** are three motor cylinders **35**, **36** and **37**, each provided, respectively, with pistons **35A**, **36A** and **37A** operatively mounted therein. The pistons are connected by their pitmans **35B**, **36B** and **37B** to crank discs **35C**, **36C** and

37C. The crank discs are secured to or formed integral with the shafts **12**, **13** and **14**, respectively, of the planet gears **9**, **10** and **11**.

The head of each cylinder is provided with a conduit **38** extending through the wall **32** and in open communication with an annular tubular pressure manifold **38A**. A hub **39** having a circumferential groove **40** therein is secured as at **41** to the housing wall **2** and partially supports the bearing **6**. A ring **42**, ported as at **43**, is secured as at **44** to and rotatable with the wall **30** of the rotatable housing **29**. The port **43** is connected as at **45** to and in communication with the manifold **38A** by means of a duct **46**. The bottom of the ring **42** is ported as at **47** and thereby in communication by means of a pressure line **48** with a source of fluid pressure (not shown).

The head of each cylinder **35**, **36** and **37** is provided with a centrally disposed poppet valve **50** seated as at **51** and provided with a stem **52** extending downwardly into its respective cylinder whereby each valve will be intermittently opened by contact with the top of its respective piston as the piston nears the completion of its up-stroke.

With the parts in their positions shown in Figure 2, the piston **37A** of cylinder **37** is starting its downward or power stroke; piston **36A** in cylinder **36** is starting its upward stroke, and piston **35A** in cylinder **35** is substantially midway of its power stroke. Pressure from the main manifold **38A** through the conduits **38** is fed progressively and automatically to the cylinders **35**, **36** and **37** by the opening of their intake valves **50**. Since the cylinders and their respective pistons and valves are identical, as is also their operation, a description of one will suffice for all. For example, and with particular reference to cylinder **37** it will be seen that as piston **37A** (assuming it is now arriving at the top of its stroke) strikes the valve stem **52**, the valve **50** will be lifted from its seat to admit into the cylinder a full charge of pressure from the conduit **38**. As the piston starts its downward stroke, the valve **50** will close, allowing the piston to complete its power stroke, at the end of which the residual pressure will exhaust through the ports **64**.

In the end wall **30** of the internal cylindrical rotatable housing **29** I provide one or more exhaust openings **66** open to the atmosphere through one or more openings **67** formed in the end wall **2** of the stationary main housing **1**.

From the foregoing it will be apparent that actual transmission of power by air from the main manifold to the motor cylinders at high velocity and with very slight loss by friction and the magnitude of forces created by the lever advantages between the pistons of the motor cylinders, planet gears, planet carrier, sun gear, and engine shaft are simple and effective and that since air develops heat on compression, the resultant expansion forces of the air within the motor cylinders will augment the power output generated by their mechanical operation.

While I have shown a particular form of embodiment of my invention, I am aware that many minor changes therein will readily suggest themselves to others skilled in the art without departing from the spirit and scope of the invention. Having thus described my invention, what I claim as new and desire to protect by Letters Patent is:

An engine comprising a stationary cylindrical main housing closed at both of its ends by end walls, an engine shaft rotatably mounted within and extending to the exterior of the housing, a rotatable cylindrical housing disposed within the main housing concentric with the engine shaft and closed at both of its ends by end walls, and provided with an intermediate wall, one of said last mentioned end walls comprising a planet carrier, a plurality of planet gears rotatably attached to the planet carrier by their shafts extending therethrough, a sleeve rotatable about said engine shaft extending to the interior of said housing and provided on its inner end with a sun gear at all times enmeshed with said planet gears, a plurality of motor cylinders fixedly secured to said planet carrier and to said intermediate wall for rotation with said rotatable housing and having pistons therein operatively connected to said planet gears, each of said cylinders closed at its outer end by a cylinder head and having a permanent exhaust opening intermediate its ends adapted to be closed by its respective piston during the down-stroke thereof and opened by the passage of the piston in completion of the down-stroke, an annular tubular fluid pressure manifold in open communication with the interior of said cylinders through said cylinder heads thereof, a hub secured to the main housing, surrounding said engine shaft and having a circumferential groove therein, fluid pressure inlet means at all times in open communication with said groove, a ring secured to said rotatable housing and rotatable about said hub, said ring having a port therein at all times in open communication with said fluid pressure manifold, valve means centrally disposed in and extending through said cylinder heads at the communicating end of said manifold with said cylinders, and each of said valve means having a stem terminating within its respective cylinder and adapted thereby to be opened by its respective piston as the piston nears the completion of its upstroke to thereby admit pressure from the manifold to the interior of its respective cylinder at the beginning of the piston power stroke, and an internal ring gear rigidly secured to one of said end walls of the main housing and surrounding said planet gears and constantly enmeshed therewith whereby one revolution of the planet carrier will impart three revolutions to the engine shaft.

References Cited in the file of this patent

UNITED STATES PATENTS

507,989	Brunler	Nov. 7, 1893
653,040	Royse	July 3, 1900
975,486	Waltman	Nov. 15, 1910

FOREIGN PATENTS

162,652	Great Britain	July 20, 1922

No. 637,661. **Patented Nov. 21, 1899.**

E. E. PETTEE & J. J. McCUTCHAN.

COMPRESSION OF AIR AND UTILIZATION THEREOF.

(Application filed Oct. 24, 1899.)

(No Model.) 2 Sheets—Sheet 1.

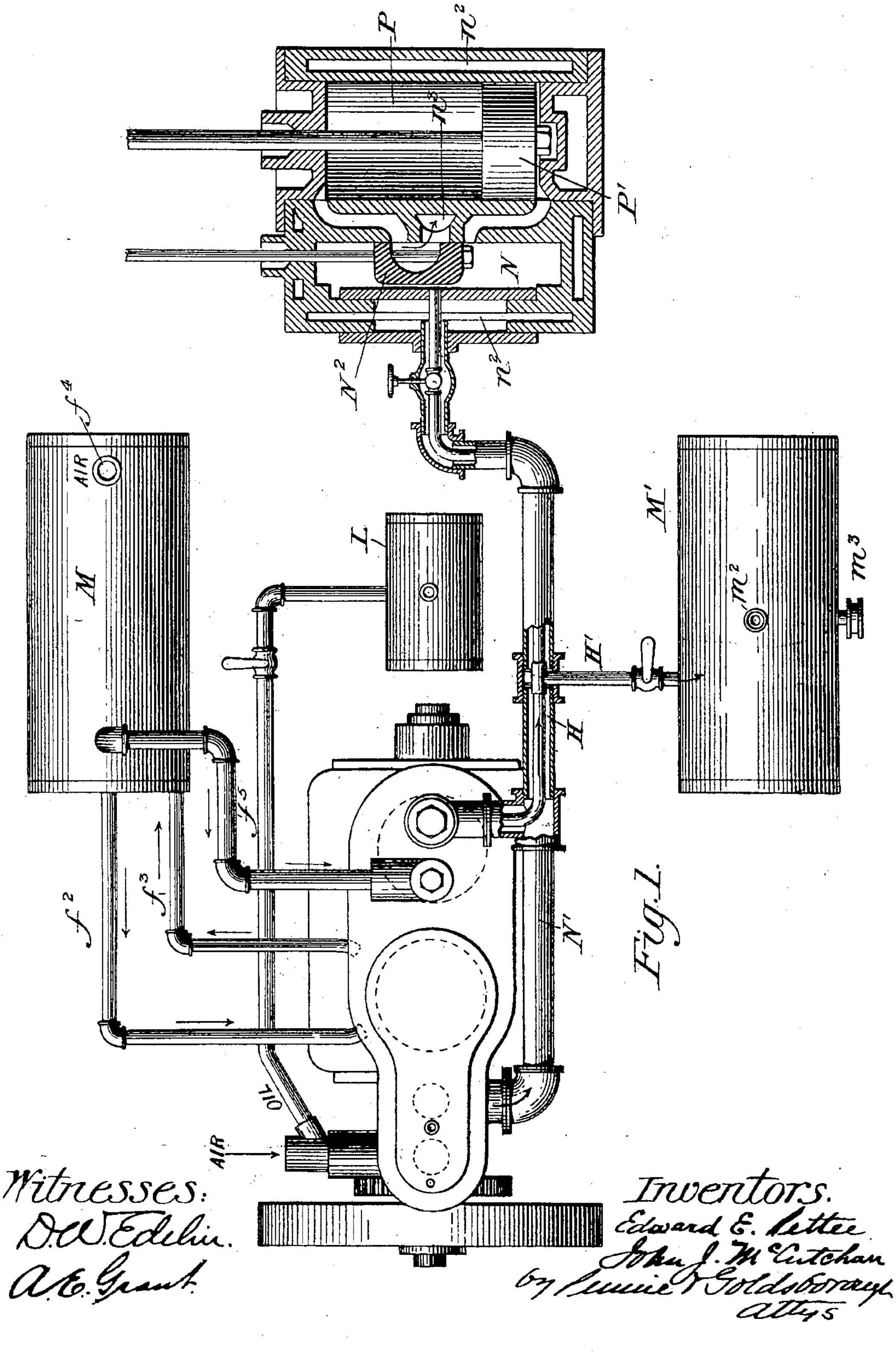


Fig. 1.

Witnesses:
D.W. Edelin.
A.E. Grant.

Inventors.
Edward E. Pettee
John J. McCutchan
by Pennie & Goldsborough
Attys

THE NORRIS PETERS CO. PHOTO-LITHO., WASHINGTON, D. C.

No. 637,661. Patented Nov. 21, 1899.

E. E. PETTEE & J. J. McCUTCHAN.

COMPRESSION OF AIR AND UTILIZATION THEREOF.

(Application filed Oct. 24, 1899.)

(No Model.) 2 Sheets—Sheet 2.

Fig. 2.

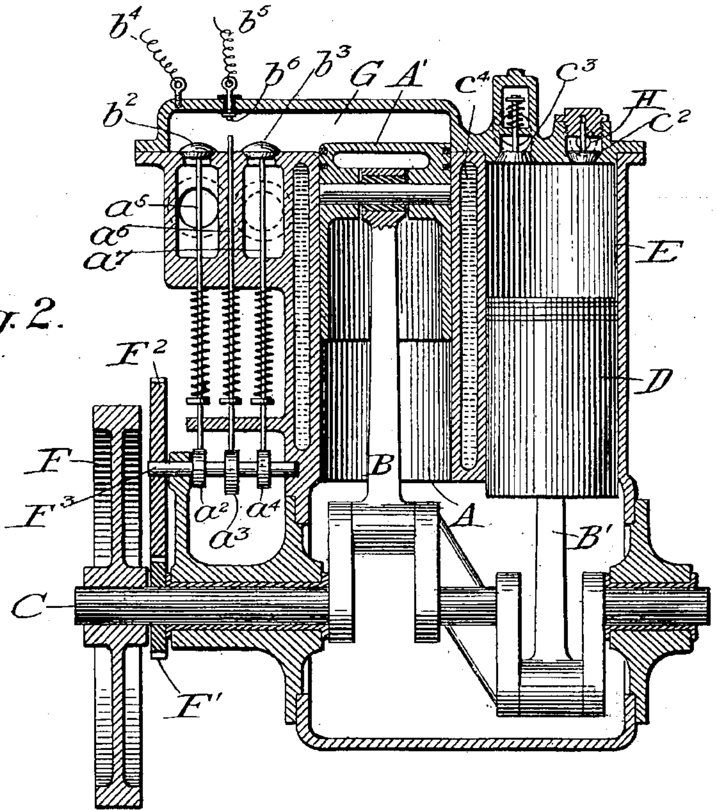


Fig. 4.

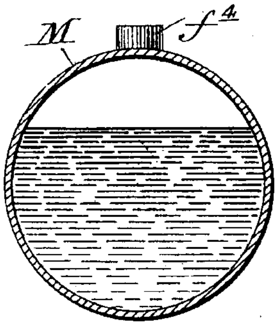
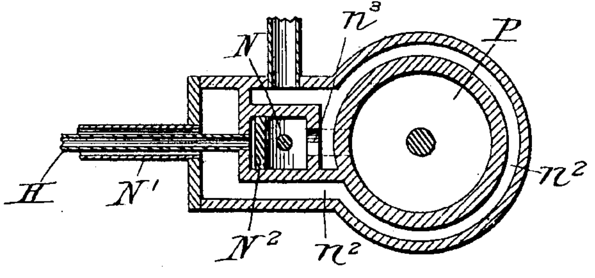


Fig. 3.



Witnesses:

D.W. Edelin.

A.E. Grant

Inventors:

Edward E. Pettee,

John J. McCutchan,

by Pennie & Goldsborough,

Attys

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

UNITED STATES PATENT OFFICE.

EDWARD E. PETTEE AND JOHN J. McCUTCHAN, OF NEW YORK, N. Y.

COMPRESSION OF AIR AND UTILIZATION THEREOF.

SPECIFICATION forming part of Letters Patent No. 637,661, dated November 21, 1899.

Original application filed March 9, 1899, Serial No. 708,421. Divided and this application filed October 24, 1899. Serial No. 734,615. (No model.)

To all whom it may concern:

Be it known that we, EDWARD E. PETTEE and JOHN J. McCUTCHAN, citizens of the United States, residing at New York, in the county of New York and State of New York, have invented certain new and useful Improvements in Compression of Air and Utilization Thereof; and we do hereby declare the following to be a full, clear, and exact description of the invention, such as will enable others skilled in the art to which it appertains to make and use the same.

In an application for Letters Patent of the United States filed by us March 9, 1899, Serial No. 708,421, we have described and claimed certain new and useful improvements in methods for compressing and utilizing air for motive purposes. The present case (which is a division of said application) relates to apparatus for carrying out said methods.

In the accompanying drawings, Figure 1 represents in plan view, partly in section, an arrangement of parts embodying our invention. Fig. 2 represents in central vertical section the compressor and the explosive-engine for operating the same. Fig. 3 represents a central section through the air-motor, and Fig. 4 represents a cross-section through the air preheating and moistening tank.

Similar letters of reference indicate similar parts throughout the several views.

Referring to the drawings, A represents the cylinder of the explosive-engine, and A' the piston thereof, said piston being connected by the oscillatory rod B with the crank-shaft C. The piston D of the air-compressing cylinder E is connected to the crank-shaft C at an angle of one hundred and eighty degrees to the crank connection of the engine-cylinder by means of the rod B'.

Upon the outer end of the crank-shaft C is mounted the balance-wheel F, fixed to the shaft, as is also the gear F', which gear meshes with the gear F^2, fixed to the cam-shaft F^3 and of twice the diameter of the gear F'. Upon the cam-shaft F^3 are fixed the cams a^2 a^3 a^4, which are adapted to actuate the corresponding rods a^5 a^6 a^7, said rods being provided with springs, as shown, for maintaining their lower ends in contact with the surfaces of the cams. To the rod a^5 is attached the valve b^2, which governs the inlet to the explosive-engine. To the rod a^7 is attached the valve b^3, which governs the exhaust of the explosive-engine, and to the rod a^6 is attached the contact for closing an electric circuit through the conductors b^4 b^5. As the rod a^6 rises it comes into electric connection with the insulated contact b^6, so that when the rod a^6 is withdrawn from the insulated contact an electric spark is formed to explode the mixture of gas and air or oil-vapor and air within the space G. The explosion of the mixture causes the piston A' to descend and drives the air-compressor piston D upwardly, thereby compressing the air in front of the piston D and causing it to pass through the exhaust-valve c^2 into the conducting-pipe H. The air-compressor cylinder is provided with an inlet-valve c^3, which opens and permits the entrance of air into the cylinder E on the downward stroke of the piston D.

To start the explosive-engine, the balance-wheel F is turned one revolution until the piston A' has descended within its cylinder and drawn air and gas or air and oil-vapor in their proper proportions through the valve b^2, which has been opened by the cam a^2 as the piston descended. When the piston reaches the downward limit of its stroke, the cam a^2 releases the rod a^5 and the valve b^2 closes. As the piston A' rises the mixture of air and gas is compressed within the space G and at the same time the cam a^3 raises the rod a^6, causing it to make contact with the insulated contact b^6. When the piston A' has reached the upper limit of its stroke, the balance-wheel F carries the shaft C somewhat past the center and the cam a^3 releases the rod a^6, which immediately drops and breaks the circuit, thereby causing an electric spark, which explodes the mixture of gas and air and forces the piston A' down within its cylinder, thereby revolving the shaft C and operating the compressing-piston D. As piston A' returns to its upper position the cam a^4 raises the rod a^7 and opens the valve b^3, thereby allowing the exploded gases to pass into the exhaust. When the piston A' has reached the limit of its stroke, the cam a^4 lets go of the rod a^7, whereupon said rod drops and closes the valve b^3. At the same time the valve b^2 opens and a new supply of gas and air is drawn into the cylinder, as hereinbefore described.

To supply the explosive-engine with fuel, we may conveniently employ a storage-receptacle L, containing either oil or compressed gas, and to abstract the heat from the wall of the expansion-cylinder to a suitable degree we provide an annular space c^4, within which water may circulate from the water-reservoir M. From the space c^4 for this purpose pipes f^2 f^3 lead into the water-reservoir M and terminate below the level of the water therein, the water-level in the reservoir M being of such height as to leave a free space above the same, through which the air for supplying the compression-cylinder may be drawn. To this end the water-reservoir is provided with an inlet f^4, so that the air entering at f^4 shall pass through and in contact with the water in the receptacle M and finally through the pipe f^5 to the air-compressor cylinder.

The pipe H leads directly to the distributing-chamber N of the motor and is jacketed throughout its entire length by the exhaust-conduit n' of the explosive-engine, so that the heat developed by the compression of the air in the compression-cylinder shall be maintained by the hot products of combustion until the compressed air is delivered into the motor. The products of combustion enter the passage n^2, which surrounds the distributing-chamber N and the cylinder P of the motor, and finally pass out through the exhaust-port n^3 of the motor, together with the expanded air from said cylinder. This latter feature is useful for preventing the formation of ice at the point of passage of the expanded air into the atmosphere, a difficulty frequently encountered, especially in cold weather, and which sometimes results in diminishing and choking the exhaust-air outlet and finally closing it, thereby stopping the motor.

The motor-cylinder is provided with a piston P', and the distributing-chest N is provided with a slide-valve N^2, the latter being operated by an eccentric or otherwise from the crank-shaft to which the piston is attached, as will be readily understood. A branch H' may be taken from the pipe H, if desired, to supply an auxiliary reservoir M', having a safety-valve m^2 and catch m^3, said reservoir being adapted to receive a reserve or surplus quantity of compressed air to assist in the operation of the motor when for a limited time its requirements are greater than would be supplied by the normal output of the compressor-cylinder.

Having thus described our invention, what we claim is—

1. The combination with an air-compressor, of an explosive-engine operating the compressor, a motor, a conducting-pipe from the compressor to the motor, and an exhaust-pipe from the explosive-engine, said exhaust-pipe jacketing the air-conducting pipe, whereby the compressed air is delivered from the compressor to the motor in such manner as to wholly utilize the heat of compression; substantially as described.

2. The combination with an air-compressor, of an explosive-engine operating the compressor, a motor, a conducting-pipe for supplying compressed air to the motor, an exhaust-pipe from the explosive-engine, said exhaust-pipe jacketing the air-conducting pipe, and the motor being provided with a chamber surrounding its working cylinder into which chamber the exhaust-pipe from the explosive-engine discharges; substantially as described.

3. The combination with an air-compressor, of an explosive-engine operating the compressor, a motor, a conducting-pipe for supplying compressed air to the motor, an exhaust-pipe from the explosive-engine, said exhaust-pipe jacketing the air-conducting pipe, and the motor being provided with a chamber surrounding its working cylinder into which chamber the exhaust-pipe from the explosive-engine discharges, said chamber exhausting with the exhaust from the working cylinder of the motor through a common exhaust-port; substantially as described.

4. A compressed-air motor provided with a working cylinder and a distributing-chest therefor, said working cylinder and distributing-chest containing respectively a piston and a slide-valve, and provided further with a chamber surrounding the working cylinder and distributing-chest, for the passage of hot gases, said exterior chamber and the working cylinder having a common exhaust; substantially as described.

5. The combination with an air-compressor and an explosive-engine operating the compressor and provided with a water-jacket, a supply-tank for obtaining the circulation of water through said jacket, said supply-tank being provided with an air-inlet opening, and a pipe leading from the supply-tank to the air-compressor, whereby the air supplied to the compressor is preheated and moistened by contact with the water in the tank and whereby it tends to lower the temperature of said water; substantially as described.

6. The combination with an air-compressor, of a motor, a conduit for supplying compressed air from the compressor to the motor, and means for maintaining the temperature of the compressed air during its entire transmission from the compressor to the motor; substantially as described.

7. The combination of an air-compressor, means for supplying warm moist air thereto, a motor, a conduit for supplying compressed air from the compressor to the motor, and means for maintaining the temperature of the

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compressed moist air during its entire transmission from the compressor to the motor; substantially as described.

8. The combination of an air-compressor, means for supplying warm moist air thereto, a motor, a conduit for supplying compressed air from the compressor to the motor, means for maintaining the temperature of the compressed moist air during its entire transmission from the compressor to the motor, and means for maintaining the high temperature of the air while it is expanding within the motor-cylinder; substantially as described.

In testimony whereof we affix our signatures in presence of two witnesses.

EDWARD E. PETTEE.
JOHN J. McCUTCHAN.

Witnesses:
ROBERT R. BLOOD,
CHAS. J. HENSLEY.

Feb. 23, 1932. F. J. RAYFIELD 1,846,656

SINGLE STAGE COMPRESSOR

Filed Nov. 15, 1929 3 Sheets-Sheet 1

Fig-1

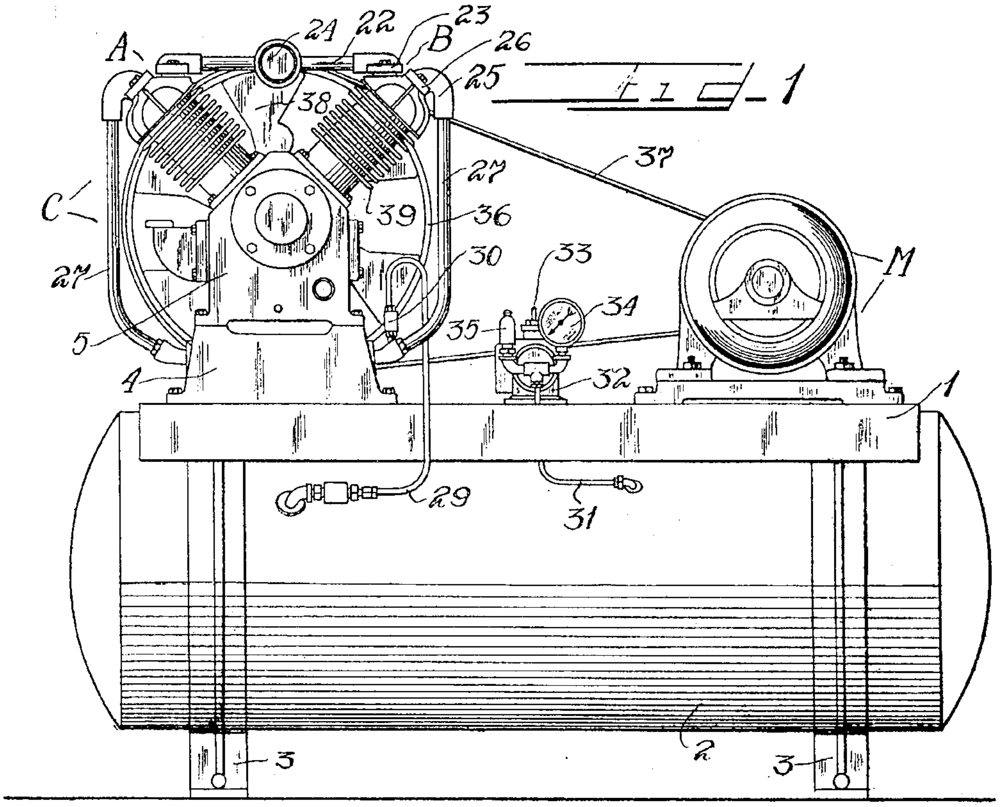
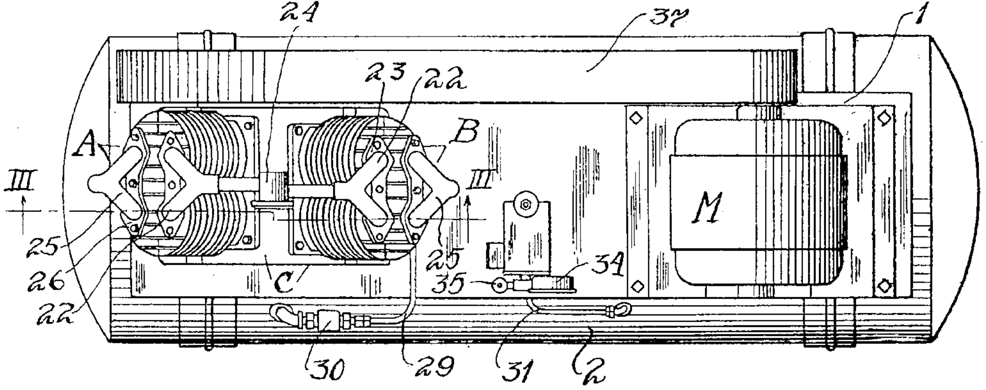


Fig-2



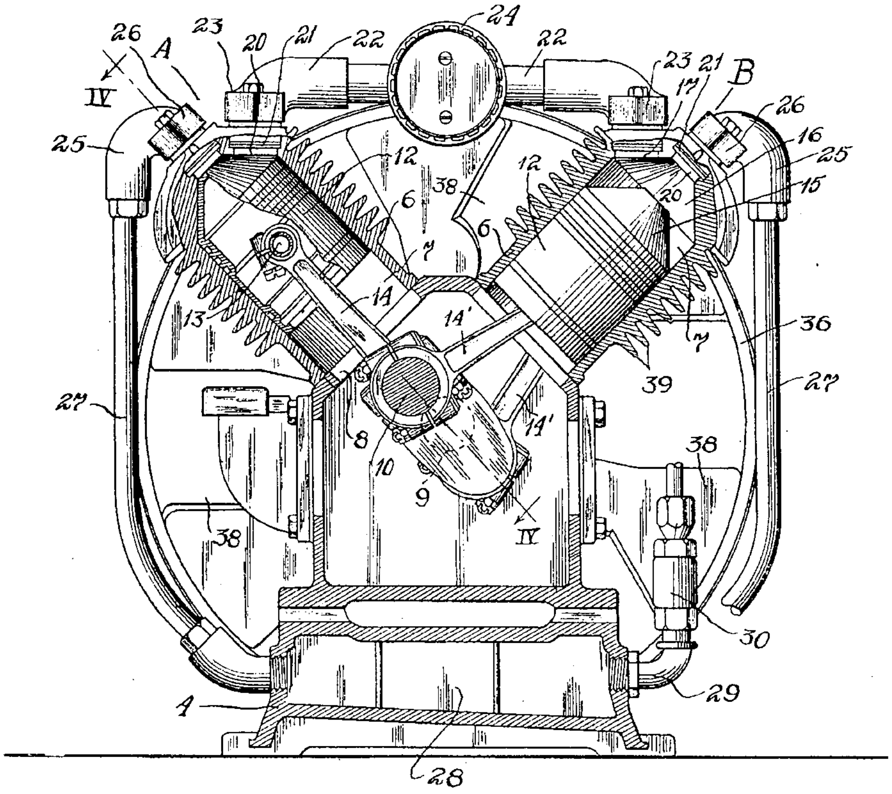
Inventor
Frederick J. Rayfield
by Charles W. Hills Attys

Feb. 23, 1932. F. J. RAYFIELD 1,846,656

SINGLE STAGE COMPRESSOR

Filed Nov. 15, 1929 3 Sheets-Sheet 2

Fig. 3



Inventor
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by Charles W. Hills Attys

Feb. 23, 1932. F. J. RAYFIELD 1,846,656

SINGLE STAGE COMPRESSOR

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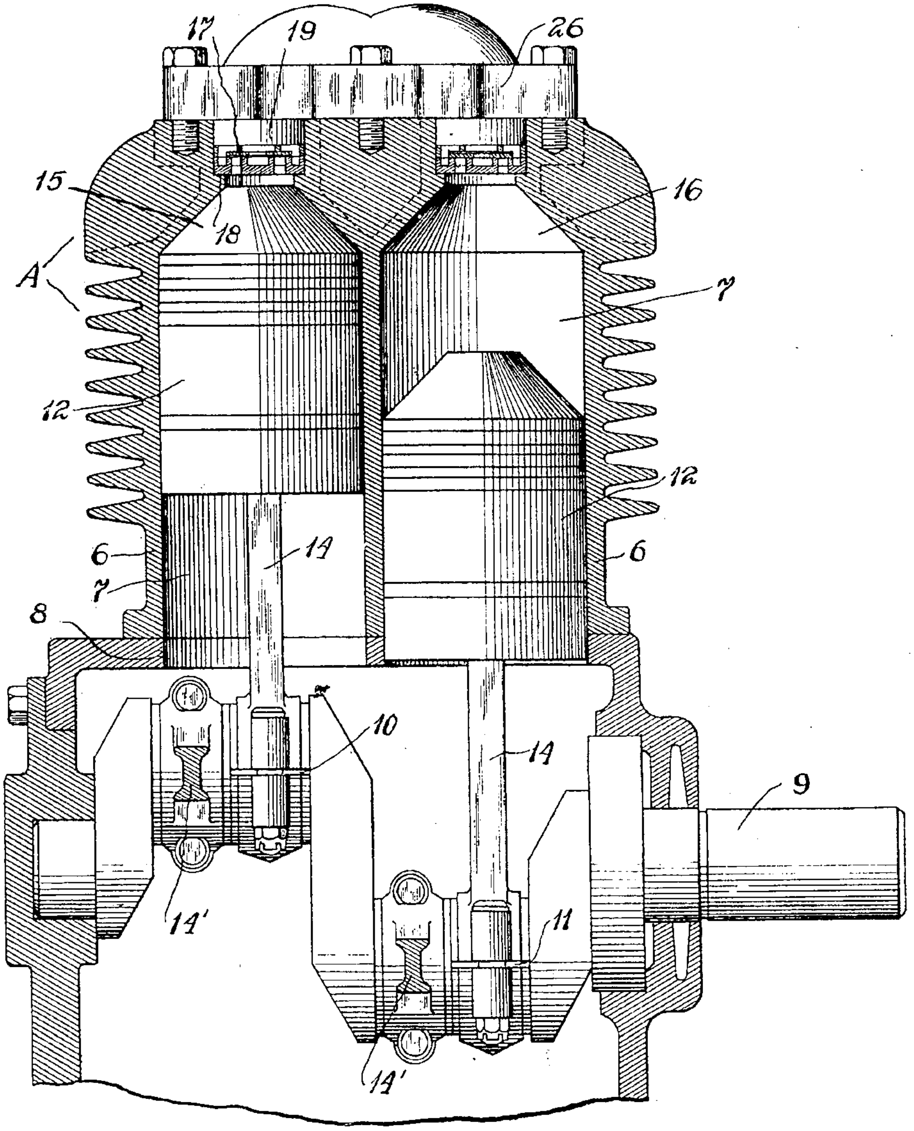
Fig. 4



Inventor
Frederick J. Rayfield
by Charles W. Hills Attys

Patented Feb. 23, 1932

1,846,656

UNITED STATES PATENT OFFICE

FREDERICK J. RAYFIELD, OF CHICAGO, ILLINOIS, ASSIGNOR TO CHAMPION PNEUMATIC MACHINERY COMPANY, OF CHICAGO, ILLINOIS, A CORPORATION OF ILLINOIS

SINGLE STAGE COMPRESSOR

Application filed November 15, 1929. Serial No. 407,384.

My invention relates to compressors, particularly to single stage compressors for compressing fluids such as air.

One important object of the invention is to provide a self-contained compressor unit for furnishing large volumes of air at high pressure.

Another important object is to arrange a plurality of cylinders in compact sets around a common crank shaft so that a very compact structure will result, and to arrange the connections of the cylinders with the crank shaft so that there will be uniform distribution of impulse and flow and reduction of vibration to a minimum.

A further object is to offset the cylinder sets on the crank case so as to permit the use of straight connecting rods with each rod having its own bearing on the crank shaft.

Another important object is to provide domed cylinder heads with correspondingly domed pistons, and to discharge the fluid from the center of the domed cylinder heads to thereby balance the operation of the pistons and to prevent pounding, and also to keep down the temperature.

A further object is to arrange the cylinders in the path of cooling air propelled by vanes provided on the flywheel pulley for the compressor.

The above enumerated and other features of my invention are exemplified in the structure shown on the drawings, on which

Figure 1 is a side elevation of my improved compressor unit;

Figure 2 is a plan view of the unit;

Figure 3 is an enlarged section on plane III—III of Figure 2, and

Figure 4 is an enlarged section on plane IV—IV of Figure 3.

As shown, the unit comprises a supporting base 1, a compressor structure C and a motor M. The driving motor may be a gasoline engine or, as shown, may be an electric motor. The reservoir 2 is supported on suitable standards 3 and the base 1 of the unit may be in the form of a channel bar and is secured on the top of the reservoir, the entire outfit thus forming a very compact structure.

The compressor structure comprises a base 4 which may be in the form of a casting and which is mounted on the supporting base 1. The crank case 5 of the compressor is mounted on the base 4, and on the crank case are mounted and detachably secured two pairs of cylinder structures A and B, each set being shown as comprising two cylinders 6 of like bore. The cylinders of each set preferably form part of an integral casting and the sets are preferably offset 45 degrees from the vertical axis of the compressor, or in other words, they are spaced 90 degrees apart on the upper part of the crank case. The bores 7 of the cylinders 6 of each set communicate at their lower ends with the interior of the crank case through openings 8.

The crank shaft 9 is journalled in the ends of the crank case and in the arrangement shown the shaft has two crank sections 10 and 11 offset 180 degrees. Each piston 12 has a wrist pin 13 from which extends a connecting rod for connection with the crank shaft. Referring to Figures 3 and 4, one piston of the set A is connected by a connecting rod 14 with the crank section 10 and the other piston of this set is connected by a rod 14 with the crank section 11. Likewise, one piston of the cylinder set B is connected by a connecting rod 14′ with the crank section 10 and the other piston of said set is connected with the crank section 11 by a rod 14′. As best shown in Figure 2, the cylinder sets are offset sufficiently in the direction of the axis of the compressor so as to permit the use of straight connecting rods, the rods being preferably of the I-beam type. The described arrangement of the cylinders and their connections with the crank shaft results in smooth and balanced operation and reduces vibration to a minimum.

The upper end 15 of each piston is frustoconical or dome-shaped and the cylinder terminates in a recess 16 which is correspondingly shaped to receive such piston end. The recess 16 of each cylinder has communication at its upper or apex end with an outlet passage 17 which is concentric with the cylinder. The passages shown are cylindrical and of comparatively large diameter and at their inner ends present annular shoulders 18 for receiving cylindrical check valve structures 19. Each cylinder has also an inlet passage 20 extending laterally from its frusto-conical recess and having a check valve 21 therein. For each set of cylinders an intake manifold fitting 22 is provided and secured by its flange 23 to the cylinder structure to communicate with the cylinder inlet passages. These manifold fittings lead from an air filter structure 24 which cleans the air before it is taken into the cylinders.

For each set of cylinders there is also a manifold fitting 25 secured by its flange 26 to the cylinder structure to communicate with the outlet or discharge passages of the cylinders. Each manifold 25 is connected by a pipe 27 with a chamber 28 provided in the base of the compressor. The cylinders take in air through the filter 24, and then compress it and discharge it into the chamber 28. With the arrangement shown, each quarter turn of the crank shaft starts a compression stroke, the distribution of impulse and load being uniform so that smooth and balanced operation results and vibration is reduced to a minimum.

The air discharged into the chamber 28 is conducted therefrom into the reservoir 2 through a pipe 29 and this pipe preferably includes a check valve 30 for preventing back flow of compressed air from the reservoir to the compressor when the compressor is not running.

Compressed air is fed from the reservoir to a pipe 31 into a housing 32 containing automatic switch mechanism (not shown) controlled by pressure to regulate the current flow to and speed of the motor. A pressure gauge 34 and a safety valve 35 may be connected with the housing 32.

On the outer end of the crank shaft is supported a drive pulley 36 connected by belt 37 with the driving motor M. The pulley is of comparatively large diameter so as to be opposite the cylinders of the compressor, and the spokes of the pulley are extended to form fan wings or blades 38 of substantial area and capacity to throw large volumes of air against the cylinders when the compressor is operated. The cylinders preferably have radiator fins or flanges 39 so that the heat of compression is rapidly conducted away from the cylinder walls and dispersed by the air propelled by the vanes. The vanes are preferably at the outer ends of the spokes of the drive pulley so that practically all of the air impelled thereby is applied to the cylinder walls to effect cooling. The vanes also add weight to the pulley so that it will act as a fly wheel for the compressor.

The arrangement involving the frusto-conical piston and the correspondingly shaped cylinder recess, together with the central discharge of the compressed air through the outlet port of large diameter, prevents wire drawing and the formation of eddy currents. The frusto-conical recess with the large outlet port forms a sort of Venturi passage through which the compressed air may flow smoothly and uniformly, and so-called pounding is entirely eliminated. The smooth and uniform flow of the air also keeps the temperature down and carbonization is reduced to a minimum. Any lubricant which may travel upwardly along the cylindrical wall of the cylinder will not be drawn into the main air flow and consequently will not escape into the pressure system, and as the arrangement described prevents the cylinder head from becoming unduly heated, any stray oil or lubricant will not be burned or carbonized. The result is a well balanced, smooth running and quiet compressor structure of large capacity and exceptional efficiency.

Changes and modifications can undoubtedly be made without departing from the spirit and scope of the invention and I do not therefore desire to be limited except as necessitated by the prior art.

I claim as my invention:

In a compressor structure, the combination of a crank case, a crank shaft, sets of compression cylinders circumferentially spaced on said crank case, pistons within said cylinders connected with said crank shaft, the inner ends of said pistons being domed and the inners ends of said cylinders being correspondingly domed, a fluid outlet for each cylinder concentric therewith and extending from the center of its domed end, a manifold conduit connecting with the fluid outlets of the cylinders of each set and communicating with a fluid reservoir, a fluid inlet for each cylinder, and check valves in said fluid outlets and fluid inlets.

In testimony whereof I have hereunto subscribed my name at Chicago, Cook County, Illinois.

FREDERICK J. RAYFIELD.

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A. REALL.

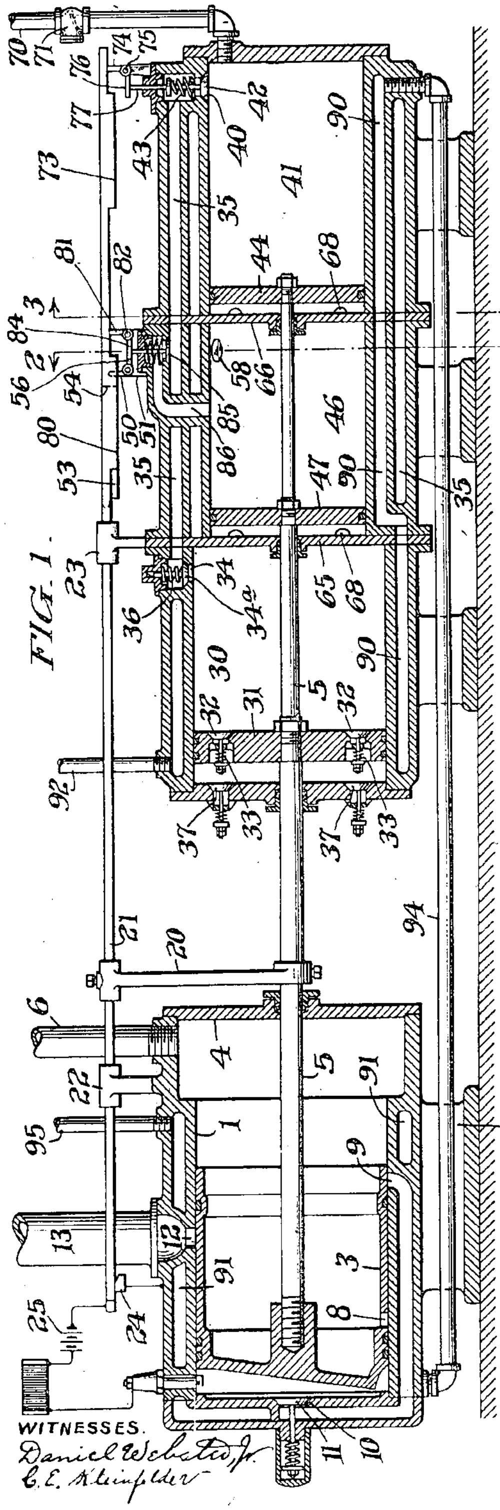
AIR COMPRESSOR AND MOTOR.

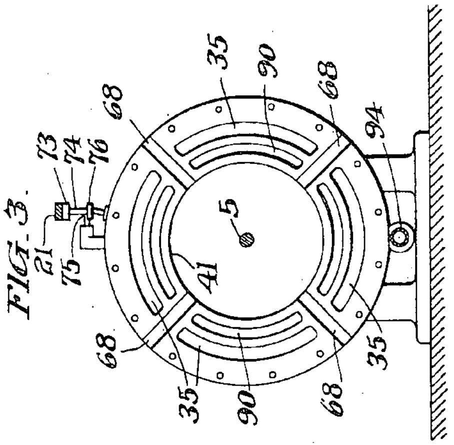
APPLICATION FILED OCT. 24, 1914. RENEWED NOV. 13, 1916.

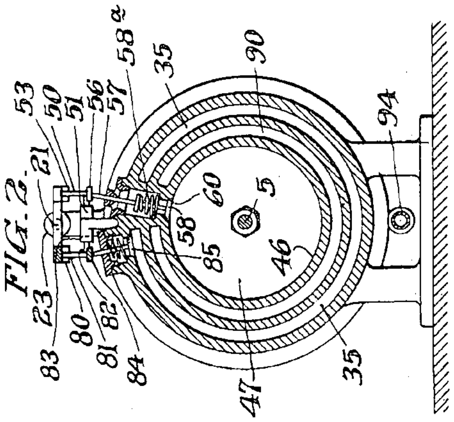
1,230,219.

Patented June 19, 1917.

2 SHEETS—SHEET 1.







WITNESSES.

Daniel Webster Jr.

C. E. Kleinfelder

INVENTOR

Arthur Reall

BY Cyrus N. Anderson

ATTORNEY

A. REALL.

AIR COMPRESSOR AND MOTOR.

APPLICATION FILED OCT. 24, 1914. RENEWED NOV. 13, 1916.

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2 SHEETS—SHEET 2.

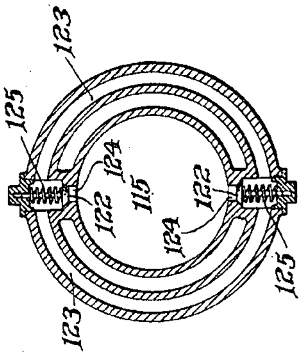
FIG. 6.

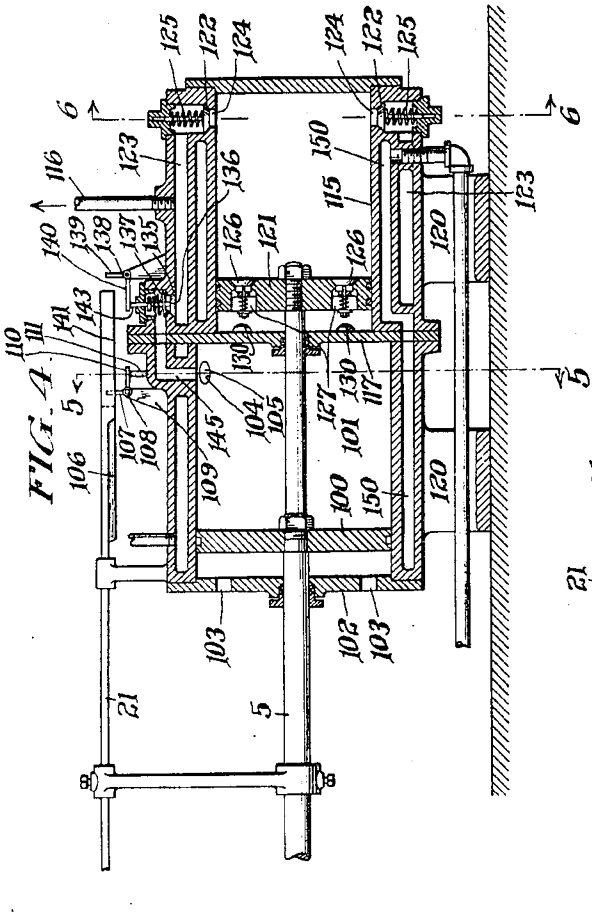
FIG. 4.

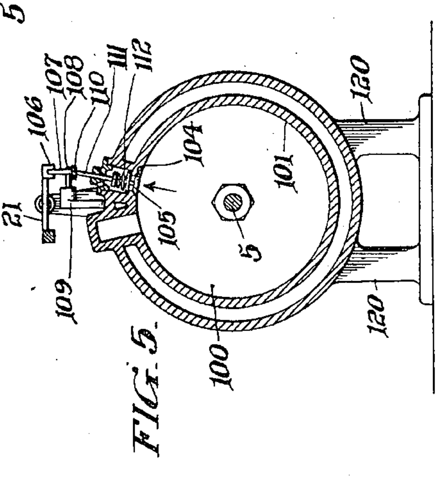
FIG. 5.

WITNESSES

Daniel Webster, Jr.

C. E. Kleinfelder

INVENTOR

Arthur Reall

BY Cyrus N. Anderson

ATTORNEY

UNITED STATES PATENT OFFICE.

ARTHUR REALL, OF PHILADELPHIA, PENNSYLVANIA, ASSIGNOR TO REALL PORTABLE COMPRESSOR COMPANY, OF PHILADELPHIA, PENNSYLVANIA, A CORPORATION OF DELAWARE.

AIR-COMPRESSOR AND MOTOR.

1,230,219. Specification of Letters Patent. Patented June 19, 1917.

Application filed October 24, 1914, Serial No. 868,368. Renewed November 13, 1916. Serial No. 131,180.

To all whom it may concern:

Be it known that I, Arthur Reall, a citizen of the United States, and a resident of the city of Philadelphia, county of Philadelphia, State of Pennsylvania, have invented certain new and useful Improvements in Air-Compressors and Motors, of which the following is a specification.

My invention relates to improvements in air compressors and motors wherein the air which has been placed under compression in a cylinder is transmitted therefrom to some point where work is to be performed and also wherein a portion of the air which is placed under compression is employed for returning the parts of the apparatus to the positions occupied by them at the time power is applied for compressing a further supply of air.

One of the main objects of my invention is to provide a construction of such character that the employment of fly wheels of the character usually employed is rendered unnecessary. By my invention I provide a construction of motor which retains its efficiency but which is at the same time exceedingly light so that it may be readily transported to points distant from the usual lines of transportation. For instance, in the development of mining properties it frequently is the case that machinery must be transported for long distances through rough sections of country lacking in transportation facilities. In such cases it is of the greatest importance that there shall be a minimum weight of material to be transported. At the same time, however, it is highly important in the development of a mining property that such machinery shall be efficient. By the employment of a machine of the character embodying my invention I conserve and provide for the efficiency of the motor while at the same time reducing the weight thereof to a minimum.

In the accompanying drawings I have illustrated certain preferred forms of construction embodying the principle of my invention but it should be understood that the same is susceptible of embodiment in other forms of construction within the scope of the claims.

In the drawings:—

Figure 1 is a longitudinal sectional view of a machine embodying my invention;

Fig. 2 is a transverse section on the line 2—2 of Fig. 1;

Fig. 3 is a view taken on the line 3—3 of Fig. 1;

Fig. 4 is a longitudinal sectional view of a portion of a machine showing a modified construction embodying the principle of my invention;

Fig. 5 is a transverse sectional view taken on the line 5—5 of Fig. 4; and

Fig. 6 is a transverse sectional view taken on the line 6—6 of Fig. 4.

Referring to Figs. 1, 2 and 3 of the drawings, 1 designates the cylinder of a gas engine supported upon the pedestal 2. The engine illustrated is a two cycle engine of known type and construction having a piston 3. This piston reciprocates in the cylinder in well known manner. The inner end of the engine cylinder is closed by means of a plate 4. 5 designates a piston rod having connection with the piston 3 in any desired known manner.

The fuel for operating the engine is introduced into the engine cylinder back of the piston through a fuel supply pipe 6.

The fuel is in gaseous form as usual and after it has been introduced it is compressed by the movement of the hollow piston 3 toward the right, having reference to Fig. 1. After the said piston has moved a certain distance toward the right the hole 8 therein reaches the outlet opening or port 9 in the side of the engine cylinder 1. When the hole 8 reaches the port 9 and passes over the same the gas which is under compression rushes from the cylinder in rear of the piston through the port and passage-way 9 into the portion of the cylinder in front of the piston head. The fuel passes into the cylinder in front of the piston through an opening 10 which is normally closed by means of a spring pressed valve 11. This valve opens as a result of the pressure of the fuel against the rear side thereof. As the fresh fuel enters the portion of the cylinder in front of the piston head 3 the exhaust gases pass therefrom outwardly through the exhaust port 12 and are led away through the exhaust pipe 13. The piston rod is connected by means of the bracket 20 with a rod 21 which extends longitudinally of the apparatus and which is supported in bearings 22 and 23, the former projecting upwardly from the gas engine cylinder while the latter is carried by another part of the apparatus which will be subsequently described. As the rod 21 reciprocates it moves into and out of contact with a member 24 so as to make and break an electric circuit which includes the battery 25 shown in Fig. 1. As a result of the making and breaking of this circuit a spark is produced interiorly of the engine so as to ignite the fuel to explode the same in the usual manner.

The connecting rod 5 projects rearwardly from the explosive engine through a couple of air cylinders and into a third. To that portion of the connecting rod which is situated within the first of the said air cylinders 30 a piston 31 is secured which piston is reciprocated in the cylinder or chamber 30. The said piston is provided with valves 32 which are normally held in closed position by means of the springs 33. When the piston 31 is moved toward the right any air which may be present in the cylinder 30 to the right of said piston 31 is compressed and is forced out through the valve closed opening 34 into the annular chamber and passage-way 35. A spring 36 tends to hold the valve 34^a in closed position. At the time that the piston 31 is moving toward the right the spring pressed valves 37 are opened by means of the external air pressure, it being understood, of course, that at such time a partial vacuum is created within the cylinder 30 upon the left hand side of the piston 31.

When the piston 31 is moved to the left by means of the piston rod 5 such air as may have previously entered the cylinder is slightly compressed so as to open the valves 32 and pass beyond the piston 31 into the cylinder chamber 30 upon the right hand side of the said piston. The air which is forced into the annular passage-way and chamber 35 fills the said chamber and flows therefrom through the opening 40 into the air compression cylinder or chamber 41. The opening 40 is adapted to be closed by means of a valve 42 held normally in closed position by means of a coiled spring 43. The rear end of the piston rod 5 projects into the chamber 41 and has secured thereto a piston plate or member 44. This plate, of course, moves to the right simultaneously with the corresponding movement of the piston 31. It is apparent, therefore, that the air passes from the annular chamber 35 into the air compression cylinder or chamber 1 only when the degree of compression of the air in the latter is less than that of the air in the annular chamber 35.

Intermediate the cylinders 30 and 41 I have provided a third cylinder 46. This cylinder is also provided with a piston or plate 47 carried upon the piston rod 5. The purpose of this cylinder and of the piston therein is to provide means for assisting to return the piston rod 5 and the piston 3 toward the left to the position shown in Fig. 1 of the drawings, at which time a new charge of fuel is brought into the engine cylinder through the fuel supply tube or pipe 6.

It is desirable at the time that the piston 47 is moved toward the right that means be provided to permit the escape of air from the said cylinder 46 so that a minimum of resistance will be offered to the movement of the piston 47 in that direction. To accomplish this purpose I have provided the pivoted bell-crank lever 50 which is supported upon a bracket 51 extending upwardly from the cylinder 46. The upwardly projecting arm of the lever is adapted to be engaged by a raised portion 53 upon the reciprocating rod 21. The forward end of this portion 53 is indicated by the dotted lines at 54. It will be seen, therefore, that immediately upon the beginning of the movement of the rod 21 toward the right this upwardly projecting arm of the lever 50 is struck by the portion 53 which causes pivotal movement of the lever so that the horizontally extending arm 56 thereof is caused to move downwardly. The said arm rests upon the upper end of a valve stem 57 having a valve 58 secured thereto upon the inside of the chamber 46. Normally the said valve is held in closed position as indicated in Fig. 2 by means of a coiled spring 58^a. Downward movement of the horizontal arm 56 of the said bell crank lever 50 causes inward movement of the valve 58^a to open the port 60 to permit the air to escape from the chamber 46 when the piston 47 is moved toward the right. It will be seen, therefore, that any air which may be present in the chamber 46 offers practically no resistance to the movement of the piston 47 and piston rod 5 toward the right.

It will be observed that the chambers 30 and 46 are separated from each other by means of a transversely extending plate 65 which is situated between and is secured to the opposing ends of the said chambers 30 and 46. It will also be observed that the chamber 46 is separated from the chamber 41 by means of the transversely extending plate 66 which is interposed between the adjacent opposing ends of the said chambers 41 and 46.

In order to permit the escape of any air which may be present in the cylinders or chambers 41 and 46 between the pistons 44 and 47 and the plates 66 and 65 respectively, I have provided the openings 68 formed by the presence of radial grooves in the adjacent ends of the cylinders or chambers 41 and 46.

The compressed air is taken from the air compression cylinder 41 and is transmitted through the pipe or tube 70 to the point where the work is to be accomplished. This pipe or tube is provided with a check valve 71 which permits the air to flow outwardly therethrough but prevents a return flow of the same.

After the pistons 31, 44 and 47 have been moved to the right as a result of the power exerted by the explosion of the fuel in the engine cylinder 1 between the head of said cylinder and the piston 3 therein it is necessary that means be provided for returning the said parts, including the piston 3, to the left into the positions indicated in Fig. 1 of the drawings. Heretofore it has been the practice to employ heavy fly wheels for that purpose. In order to obviate the necessity of employing such wheels I have provided means whereby the compressed air may be employed or used for that purpose.

The rear or right hand end of the longitudinally reciprocating rod 21 is provided with a raised portion 73 which is adapted to contact with the upwardly projecting portion 74 of the bell crank lever which is pivoted at 75. The horizontal portion 76 of this bell crank lever rests upon the upper end of a rod 77 upon the inner lower end of which the valve 42 is carried. As the rod 21 moves toward the right the bell crank lever is moved about its pivot so as to lift the horizontal portion 76 thereof away from the rod 77 but when it moves toward the left the contact of the raised portion 73 with the arm 74 causes a pivotal movement of the bell crank lever in the opposite direction so as to depress the arm 76 and open the valve 42. At the same time the raised portion 80 upon the reciprocating rod or bar 21 contacts with the upwardly extending portion 81 of the bell crank lever which is pivoted at 82 upon a bracket 83 extending upwardly from the cylinder 46. The contact of the raised portion 80 upon the rod or bar 21 with the portion 81 of the lever, as the said bar moves toward the left, causes downward movement of the arm 84 of the bell crank lever which is pivoted at 82 to depress the valve 85 and open the port leading into the passage way 86. The positions or locations of the left hand ends of the raised portions 73 and 80 upon the reciprocating rod 21 are such that immediately at the beginning of the movement of the said rod or bar 21 toward the left the said raised portions contact with the arms 74 and 81 to open the valves 42 and 85 so that the air which is under compression in the cylinder 41 and in the annular chamber 35 surrounding the cylinders 41 and 46 have access to the chamber of the cylinder 46. It will be seen, therefore, that the compressed air acts upon both the pistons 44 and 47 to cause a return movement thereof and of the piston 31, the connecting rod 5 and the piston 3 in the engine cylinder.

In order to prevent the gas engine cylinder and the air compression and expansion cylinder from becoming too greatly heated I have provided cooling chambers 90 and 91 to which water is introduced through the supply pipe 92 having connection with the chamber 90. From the latter chamber the water is conducted by the pipe 94 to the annular water chamber 91. From the latter it may be conducted or withdrawn through the discharge pipe 95.

In Figs. 4, 5 and 6 I have shown a modified construction in which two air chambers or cylinders are employed instead of three as in the construction shown in Figs. 1, 2 and 3.

In this modified construction a piston 100 is located within an air cylinder or chamber 101 and is secured upon the connecting rod 5. The left hand end of the cylinder or chamber 101 is closed by means of a plate 102 having holes 103 therethrough through which the air has free access to the interior of the cylinder 101 at the left of the piston 100. The only purpose of the plate 102 is to serve as a support or guide for the piston rod 5. As the piston rod 5 and the piston 100 move toward the right any air which may be situated in the cylinder or chamber 101 is permitted to escape through a port 104. This port is normally closed by means of a valve 105 but as the rod 21 is moved toward the right the raised portion 106 thereon contacts with the upwardly projecting arm 107 of the bell crank lever which is pivoted at 108 upon the bracket 109 upon the cylinder or chamber 101. The horizontally extending arm 110 of the said bell crank lever contacts with the upper end of a rod 111 to the lower end of which the valve 105 is secured. It will be seen, therefore, that as the rod 21 moves toward the right the valve 105 is depressed in opposition to the spring 112 so that any air which may be present in the cylinder or chamber 101 is permitted to escape with the result that it offers practically no resistance to the movement of the piston 100 toward the right.

115 designates an air compression cylinder from which air is supplied through the pipe 116 to the point where work is to be accomplished. The cylinder or chamber 115 is separated from the cylinder or chamber 101 by means of a plate 117. The adjacent opposing ends of both of the cylinders 101 and 115 are secured to this plate. It may be noted here that both of the cylinders 101 and 115 are supported upon the pedestal 120.

121 designates a piston which is situated within the cylinder or chamber 115 and which is secured to the inner end of the piston rod 5. As the piston 121 is moved toward the right any air which may be present in the cylinder or chamber 115 is compressed. As a result of such compression the valves 122 are opened to permit the passage of air from the cylinder or chamber 115 into the annular chamber 123 through the ports 124. Normally the valves 122 are held in closed position by means of the coiled springs 125. When the piston 121 moves toward the left it will be understood that a partial vacuum is created within the cylinder or chamber 115 so that the external air pressure is sufficient to open the spring pressed valves 126 to permit the passage of air through the ports 127 in the piston 121 into the cylinder or chamber 115. The air passes into the portion of the cylinder 115 between the plate 117 and the piston 121 through openings 130 formed in the end of the said cylinder 115 adjacent to the plate 117.

For the purpose of returning the pistons 100, 121 and the piston rod 5, together with the piston 3 of the engine cylinder, to the left, I provide means whereby the air under compression in the annular chamber 123 may escape from the latter into the cylinder or chamber 101. To accomplish this I provide a port or opening 135 which is closed normally by a valve 136 said valve being held in closed position by means of a spring 137. A bell crank lever pivoted at 138 is provided with an upwardly projecting arm 139 and horizontal arm 140. The reciprocating rod 21 is provided with a raised portion 141 which is adapted to contact with the upwardly projecting portion 139 of the said bell crank lever. As the raised portion 141 moves toward the right the bell crank lever is moved on its pivot without affecting the valve 136 but when moved in the opposite direction the horizontal projecting arm 140 of the said bell crank lever is depressed and being in contact with the upper end of the rod 143 depresses the same so as to open the valve 136. As soon as this valve is opened the air, as a result of expansion, rushes through the passage-way 145 into the chamber 101. Its expansive force is then exerted upon the rear side of the piston 101 to return the said piston, together with the parts connected therewith, toward the left.

As in the construction shown in Figs. 1 and 3, I provide an annular water cooling chamber 150 for preventing said cylinders 101 and 115 from becoming over-heated.

It will be understood that in both forms of construction the pistons reciprocate very rapidly and that there is at all times a sufficient amount of air under compression and in communication either with the pipe 70 or the pipe 116 leading to the points where the work is being done, to furnish the necessary power to accomplish the work to be done, and also that there is an excess of such compressed air sufficient to perform the work of compressing the gaseous fuel in the gas engine to such extent as may be required to effect efficiency of operation; also it will be understood that the gas remaining under compression at the right of the pistons when they occupy their extreme right hand positions is sufficient to start a movement of the pistons to the left before the opening of the valves 42 and 85.

Any suitable known means of starting gas engines may be employed to start the operation of the apparatus embodying my invention.

I claim:—

1. In an apparatus of the character described, the combination of a plurality of cylinders, pistons in said cylinders, means for driving the said pistons in one direction to compress air in one or more of said cylinders, means for conducting a portion of the air so compressed to a point outside of said cylinders, and means whereby a portion of the compressed air is permitted to act upon one or more of said pistons to drive the same in the opposite direction.

2. In an apparatus of the character described, the combination of a plurality of cylinders, pistons in said cylinders, means for driving the said pistons in one direction, means whereby air is introduced into and compressed in one of said cylinders, means for conducting the air under compression from said cylinder to a point outside of said cylinders, and means for permitting a portion of the said air under compression into another of said cylinders to drive the said pistons in the opposite direction.

3. In an apparatus of the character described, the combination of a plurality of cylinders, pistons in said cylinders, a power device for driving the said pistons in one direction, means for permitting air under atmospheric pressure into one or more of said cylinders, which air is placed under compression by one or more of the said pistons, means for conducting a portion of the air under compression to a point outside of the said cylinders, and means for controlling the admission of a portion of the said compressed air into another one of the said cylinders for acting upon the piston in said other cylinder for driving the said pistons in the opposite direction and for placing the said power device in its initial condition.

4. In an apparatus of the character described, the combination of an explosive engine having a piston and a piston rod connected to the latter, a plurality of cylinders into which the said piston rod extends, pistons secured to said piston rod, which pis-

tons are situated in the said cylinders, means for admitting air into one or more of said cylinders and compressing the same therein, means for conducting a portion of the said air to a point outside the said cylinders, and means for permitting a portion thereof to enter another one or more of said cylinders to act upon the piston or pistons therein to return the same to intitial position.

5. In an apparatus of the character described, the combination of a plurality of cylinders, a piston rod extending into the said cylinders, pistons situated in said cylinders and secured to said piston rod, means for permitting air to enter one of the said cylinders, means for driving the said pistons in one direction to compress the air in said cylinder, one or more of the said cylinders having an annular chamber surrounding the same, means for permitting air under compression to enter the said annular chamber, means for conducting the air from said annular chamber to a point outside of the said cylinder, and means for permitting the air to flow from the said annular chamber to one of the said cylinders for driving the said pistons and piston rod in the opposite direction.

6. In an apparatus of the character described, the combination of a plurality of cylinders, an explosive engine having a piston and a piston rod, said piston rod projecting into the said cylinders, pistons situated in the said cylinders and secured to the said piston rod, means for permitting access of air to one of said cylinders in rear of the piston therein to be compressed thereby when the piston rod is driven outwardly by the said explosive engine, one or more of the said cylinders having an annular chamber surrounding the same, means for permitting the air compressed in said cylinder to escape into the said annular chamber and means for permitting a portion of the air under compression in the said annular chamber to escape into another one or more of the other of said cylinders to act upon the pistons therein to return the said pistons and the piston rod in the opposite direction.

7. In an apparatus of the character described, the combination of a plurality of cylinders, one of the said cylinders being of greater transverse dimension than the other or others of said cylinders, a rod extending into said cylinders, pistons situated in said cylinders and secured to said rod, means for permitting air at atmospheric pressure to enter the cylinder having the greater transverse dimension, means for driving the said rod and the said pistons in one direction whereby the air which has entered the said cylinder is compressed, means for permitting the escape of the air under compression from said cylinder of greater transverse dimension, means for conducting a portion of said air under compression to a point outside the said cylinder, and means for conducting a portion thereof to one or more of the other of said cylinders to act upon the pistons therein to drive the said pistons and the said rod in the opposite direction.

8. In an apparatus of the character described, the combination of an explosive engine having a piston and a piston rod, a plurality of cylinders arranged in alinement with the said explosive engine, and into which the said piston rod extends, pistons situated in the said cylinders and being secured to the said piston rod, means whereby air under atmospheric pressure is permitted to enter one of the said cylinders, the air thus admitted being placed under compression by movement of the piston in the said cylinder in one direction, a chamber for receiving the compressed air from said cylinder, passage-ways for conducting the air from said chamber into one or more of the other of said cylinders, valves for closing the said passage-ways, and means having connection with the said piston rod for causing actuation of the said valves to open the said passage-ways to permit the flow of air from said chamber into the said cylinder or cylinders.

9. In an apparatus of the character described, the combination of an explosive engine having a piston and a piston rod, a plurality of cylinders arranged in alinement with the said explosive engine and into which the said piston rod extends, and one of the said cylinders having a greater transverse dimension than the other of said cylinders, means for permitting air under atmospheric pressure to enter the said cylinder having the greater transverse dimension, a chamber for receiving the air from the said cylinder of greater transverse dimension, means for conducting the air from said chamber to a point or points outside of said cylinders, a passage-way leading from the said chamber to another one of the said cylinders of smaller transverse dimension, a valve for closing the said passage-way, and means having connection with the said piston rod and reciprocating therewith for causing the opening of said valve to permit the passage of a portion of the air under compression in said chamber into the said cylinder of smaller dimension to act upon the piston therein to return the same together with the piston rod in the opposite direction.

10. In an apparatus of the character described, the combination of three cylinders arranged in alinement with each other, one of the said cylinders being of greater transverse area than the other of said cylinders, a rod extending into said cylinders, pistons situated in said cylinders and connected to

said rod, means for permitting air under atmospheric pressure to enter the cylinder having the greater transverse area, means for driving the said rod and the said pistons in one direction whereby the air which has entered the said cylinder is compressed, a chamber surrounding the others of said cylinders, means for permitting the air compressed in the cylinder having the greater transverse area to escape into the said chamber, means for conducting a portion of the air so compressed to a point outside of the said cylinders, passage-ways leading from the said chamber to each of the other cylinders, valves for closing the said passage-ways, a bar having connection with the said rod and reciprocating therewith, said bar being arranged and supported in parallel relation with the said cylinders, and means interposed between the said bar and the said valves for opening the latter to permit the entry of air from the said chamber into the said cylinders to thereby move said pistons and the said rod in the opposite direction.

11. In an apparatus of the character described, the combination of an explosive engine having a piston and a piston rod, a plurality of cylinders into which the said piston rod extends, one of the said cylinders having a transverse area greater than that of the transverse area of the other cylinder or cylinders, a bar having rigid connection with the said piston rod and supported in parallel relation to the said cylinders, said bar reciprocating with the said piston rod, pistons in the said cylinders, which pistons are secured to the said piston rod, means for permitting air under atmospheric pressure to enter the said cylinder having the greater dimension, a chamber surrounding the other of said cylinders, means for permitting the air under compression to enter the said chamber, means for permitting the air to escape from the said other cylinder when the air in the first-named cylinder having the greater dimension is being compressed, means for conducting a portion of the air from said chamber to a point outside the said cylinders, a passage-way leading from said chamber to the said other cylinder of smaller transverse area, a valve for closing the said passage-way, and means interposed between the said reciprocating bar and the said valve whereby the latter is opened to permit the passage of a portion of the air under compression from said chamber into the said chamber having the smaller transverse area to act upon the piston therein to return the same together with the piston rod in the opposite direction to that in which the same travels to compress the air in the cylinder having the greater transverse area.

12. The combination of an internal combustion engine having a piston, an air compressor comprising a plurality of cylinders, pistons operating in said cylinders, a piston rod connecting the said pistons in the said cylinders with the piston in said engine, and means whereby air under compression in the said cylinders causes return movement of the said pistons to compress the gas with which the said engine has been charged.

In testimony that I claim the foregoing as my invention, I have hereunto signed my name this 23rd day of October, A. D. 1914.

ARTHUR REALL.

In the presence of—
E. W. Smith,
C. E. Kleinfelder.

Feb. 3, 1948. A. H. ROSENTHAL 2,435,548

HIGH VACUUM PUMP

Filed Nov. 5, 1943 2 Sheets-Sheet 1

Fig. 2.

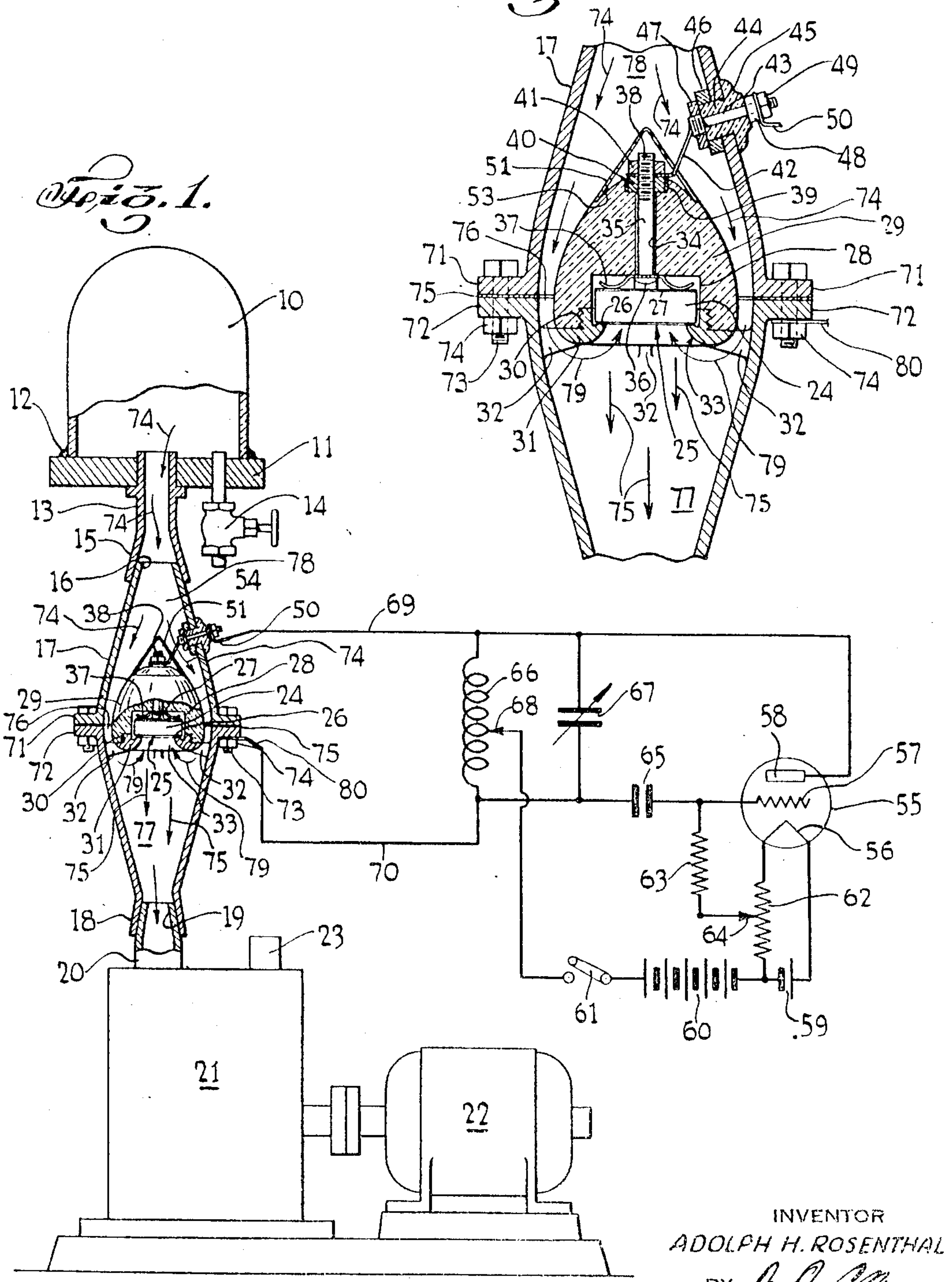

Fig. 1.

INVENTOR
ADOLPH H. ROSENTHAL
BY J. O. Oliver,
ATTORNEY

Feb. 3, 1948. A. H. ROSENTHAL **2,435,548**

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Fig. 3.

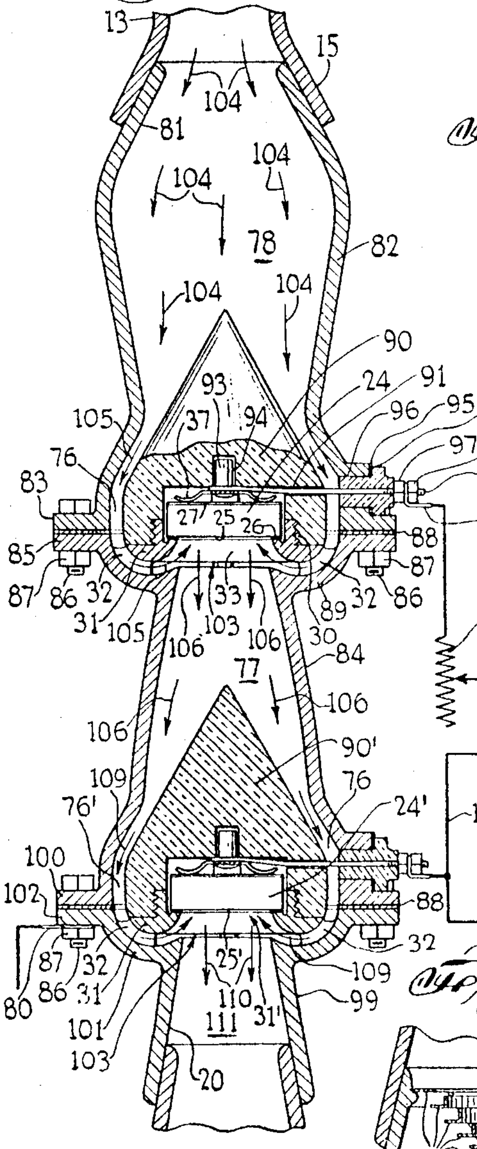


Fig. 4.

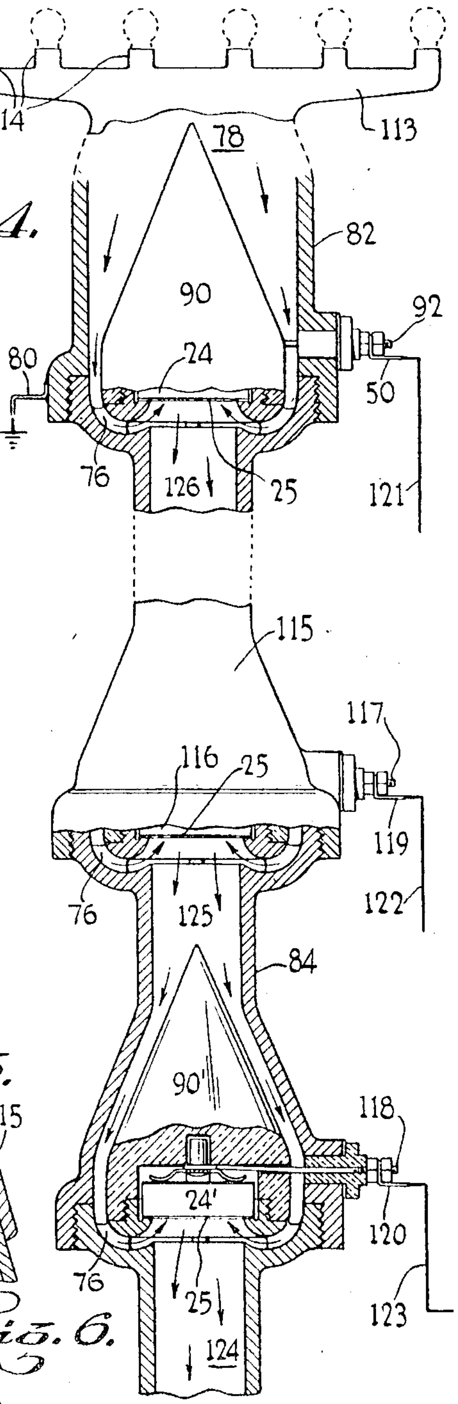


Fig. 5.

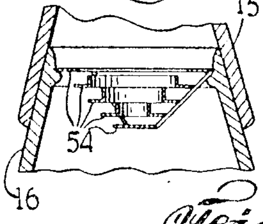
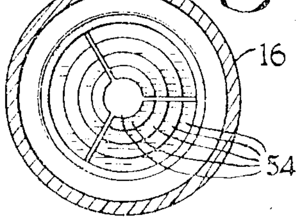


Fig. 6.



INVENTOR
ADOLPH H. ROSENTHAL
BY J. O. Ollier,
ATTORNEY

Patented Feb. 3, 1948

2,435,548

UNITED STATES PATENT OFFICE

2,435,548

HIGH VACUUM PUMP

Adolph H. Rosenthal, New York, N. Y., assignor
to Scophony Corporation of America, New
York, N. Y., a corporation of Delaware

Application November 5, 1943, Serial No. 509,144

14 Claims. (Cl. 230—1)

This invention relates to a method and apparatus for rarefying vapors or gases, in particular air, within confined space and thereby producing a vacuum of desired high degree. Single- or multi-stage pumps have been suggested for this purpose, working on different principles.

In pumps operating on the injector principle, a liquid, preferably water or mercury, or vapor was injected through a nozzle into the confined space either in a solid or whirling jet which imparted an impetus to the gas as well as trapped some of it, and upon leaving the confined space carried along thus accelerated and trapped gas.

The effect of this type of pump was limited by the vapor pressure developed by the liquid or vapor used as a working medium which depends on the prevailing temperature. The low pressure obtainable by this type of pump is thus limited and they are used mostly for producing vacua of moderate degree and as auxiliary or backing pumps for other, more efficient vacuum pumps.

Another type of pump used in the vacuum technique for producing moderate vacua is of the reciprocating piston type, the efficiency of which was increased by filling its dead spaces or clearances with liquids of high boiling point, such as oil or mercury. Here again the vapor pressure of these liquids limited the degree of vacuum attainable by their use; leakage losses in the valves and through the packings of the piston rod, etc., caused additional difficulties. The vacuum attainable by this type of pump is considerably better than that of ejector pumps, but does not suffice to produce high vacua as required in many branches of today's vacuum technique and they are used, therefore, as auxiliary or backing pumps to produce a "pre-vacuum" for more effective pumps of other types. Rotating pumps of the vane and gear type are of similar effect and use.

Vacuum pumps which permit the production of extremely high vacua, i. e. extreme rarefaction and consequential extremely low pressures of a gas, operate either on the principle of gas diffusion into streaming, particularly injected vapors of mercury or oil, or on the "molecular" principle. The performance of the vapor diffusion pumps is limited by the vapor pressure of the working medium, and their operation is complicated by the heating means required for vaporizing the working medium, and by cooling means. The "molecular" pumps make use of the quite fundamentally changed behaviour of gas when its rarefaction is extended so far that the "mean free path" of the individual gas molecules is larger than the dimensions of the space in which the gas is confined.

At a given temperature, the pressure of a gas is proportional to the number of gas molecules in a unit of volume. At atmospheric and considerably lower pressure, the gas molecules within a unit of volume fly irregularly in every direction, collide frequently and change thereby the directions of their flight. Hence the direction of flight of the individual gas molecule is undefined. Even if an impact is exerted upon it in a certain direction, its thus directed path will be terminated soon upon collision with other molecules. However, if the rarefaction of the gas exceeds a certain degree (and the gas pressure is thereby reduced below a certain value), the average or mean path which a molecule follows freely without colliding with another one, is extended so far that its hitting upon and being reflected by the wall of the confined space is much more likely than its colliding with another gas molecule. In such a state of rarefaction and at such a low pressure in the gas, the individual gas molecules are therefore eminently capable of being directed by a moving surface upon which they impinge. The mean free paths of the molecules of various gases used in the vacuum technique at decreasing gas pressures have been calculated and verified by experiments, and are therefore well known. With air, a state in which the mean free path of its molecules exceeds usual dimensions of spaces in which the air is to be rarefied, is attained at pressures of about 0.001 mm. mercury column, and such and lower air pressures are commonly termed a true high vacuum.

The "molecular" pump type utilizes this behaviour of gas under low pressure. The molecules of a pre-rarefied gas are admitted to the pump space and permitted to impinge upon the circumference of a rapidly rotating drum which reflects as well as imparts to them a velocity component in the direction of its rotation; the thus repeatedly reflected molecules are transported towards and through the outlet of the pump space into another space. As a consequence, the number of gas molecules in that other space is increased, resulting in increase of pressure, while the space from which the gas molecules flew upon the circumference of the rotating drum is depleted of gas molecules and the pressure therein reduced, finally resulting in an extremely high vacuum. The efficiency of this type of pump and the degree of vacuum attainable are limited by the maximum circumferential speed of the rotating drum on which its effect depends, by inevitable leakage in the bearings of the drum shaft, etc.

The invention is concerned with a method of rarefying vapors and gases and an apparatus or pump therefor which also utilizes the behaviour of a sufficiently pre-rarefied gas (or vapor) just described, viz. that its molecules can be directed and accelerated effectively by mechanical action upon them, and it is an object of the invention to improve vacuum pumps, particularly high vacuum pumps working on this "molecular" principle.

In particular, it is an object of the invention to eliminate the disadvantages attendant upon diffusion or diffusion-ejector high vacuum pumps which use vapors of boiling liquids, and to do away with the heating and cooling means of those pumps. According to the invention, no liquids and vapors are used at all for producing the high vacuum.

It is another object of the invention to eliminate rotating or reciprocating members of a high vacuum pump, such as used heretofore in the rotating molecular pump or with reciprocating piston pumps in which the clearance is reduced by means of high boiling liquids. Thereby the difficulties attendant upon these pumps as to fast moving parts and leakages in bearings of a drum shaft or packings of a piston rod, etc. are avoided.

It is still a further object of the invention to increase the efficiency of the mechanical action upon the gas molecules of a pre-rarefied gas, by subjecting them to an immediate directing impact by a vibrating surface rather than reflection by a surface which rotates at high speed in one direction.

It is a further object of the invention to utilize the effect of supersonic vibrations of a mechanical vibrator upon gas, for producing high vacua or extremely low gas pressures.

It is still another object of the invention to provide a method of producing high and highest vacua and a relatively small and compact apparatus therefor, the active elements of which are entirely within the space in which the gas undergoing rarefaction is confined, are stationary and actuated electrically, and the intensity of action of which can be regulated electrically from outside the confined space without resort to any movable part passing a wall of that space.

These and other objects of the invention will be more clearly understood when the specification proceeds with reference to the drawings in which Fig. 1 shows rather schematically in vertical cross-section, with parts in elevation, a single-stage high vacuum pump according to the invention and diagrammatically an electric circuit for exciting supersonic mechanical vibrations of a vibrator used by the invention, Fig. 2 in vertical cross-section and at a larger scale the arrangement of a piezo-electric vibrator in the example of Fig. 1, Fig. 3 in vertical cross-section and partly in elevation a two stage pump according to the invention, Fig. 4 in a similar manner a multi-stage pump according to the invention connected with a manifold for evacuating bulbs, and Fig. 5 in vertical cross-section and Fig. 6 in a view from below, the arrangement of baffles in back of a vibrator unit as used by the invention and shown in Fig. 1.

Referring to Fig. 1, there is shown as a vessel or container to be evacuated, a bel-jar **10**, e. g. of steel or glass, placed upon a pump plate **11**, e. g. of steel, the upper surface of which is preferably ground and polished so as to provide an air-tight fit with the equally ground lower edge of bell-jar **10**. Sealing wax or a gasket **12** may be applied between the bell-jar and pump plate. A pipe **13** is air-tightly fitted into a corresponding aperture of plate **11** and conically widened at its lower end **15**. A duct provided with a manually operated valve **14** passes another aperture in plate **11** and is air-tightly mounted therein; valve **14** permits the interior of jar **10** to be connected with and shut off from the surrounding atmosphere.

A longitudinal vessel **17**, e. g. of steel, open at and tapering towards both of its ends engages with its uppr end **16** the interior of conical end **15** of pipe or duct **13**. The engaging surfaces of the ends **15** and **16** are preferably ground into one another in order to secure an air-tight connection; they may be sealed additionally with a suitable sealing compound. The lower end **18** of vessel **17** is conically enlarged and fitted upon an equally conical end **19** of an intake duct **20** leading to the suction side of a pre-vacuum pump **21**. The engaging surfaces of the conical parts **18**, **19** are preferably ground into one another and sealed, in order to secure their air-tight connection. Vacuum pump **21** is of any type suitable to produce a pre-vacuum, such as a vane-pump, and driven by an electromotor **22**. **23** is an outlet of vacuum pump **21**.

A mechanical vibrator capable of being electrically excited to supersonic vibrations of suitably high frequency, preferably of between about 100,000 to 10,000,000 cycles per second is arranged within vessel **17**. The vibrator consists in this exemplification of the invention of a piece **24** of piezo-electric material, such as quartz, tourmaline, Rochelle salt, etc. The piece is cut from crystalline piezo-electric material in well known manner, along two parallel planes which are perpendicular to a polar axis of the piezo-electric crystal; such cuts of quartz crystals are known for instance as "Curie-cut" or "X-cut." Some piezo-electric crystals, e. g. quartz crystals, exhibit more than one, e. g. three polar axes, and the distant parallel planes along which the piece is cut from the crystal, may be perpendicular to any one of them. The direction of the mechanical resonance vibrations excited in a thus cut piece may be parallel to the selected polar axis and therefore perpendicular to said parallel planes. The vibrations in the direction of one of those polar axes produced by an alternating electric field in the direction of this axis are termed "longitudinal" or "thickness" vibrations, and their resonance frequency depends mainly on the thickness of the piece. Although other types of vibrations, such as transverse vibrations may be produced and utilized, thickness vibrations are generally preferred. The vibrations can be excited by application of recurrent electric impulses or oscillatory energy, particularly of a sinusoidal voltage to suitable electrodes placed upon two distant parallel planes, and the vibrations are particularly strong if the frequency of the alternating electric voltage essentially equals the mechanical resonance frequency of the piece within narrow range. The crystal piece may also be excited to vibrations of an odd integer multiple frequency of its fundamental resonance frequency, and such odd harmonic vibrations can be used to advantage by the invention. The energy of the mechanical resonance vibrations depends upon that of the applied electric impulses; voltages from several hundred to several thousand volts can be used.

Now referring to Figs. 1 and 2, it is assumed that crystal piece **24** is cut from a quartz crystal in such manner that thickness vibrations result, and that it has the shape of a cylindrical plate the cylindrical circumference of which is parallel and the plane front surfaces of which are perpendicular to the selected polar axis. Front surface **25** is essentially freely exposed and contacted near its edge only by a ring-shaped electrode 26; the rear surface of piece 24 is covered by an electrode 27. The ring and full electrodes may be cut from metallic sheet material and pressed or cemented onto piece 24, or one or both of them may be applied to piece 24 by vacuum evaporation or sputtering upon the respective surface suitable electrode material such as copper, aluminum, etc. The electrode on front surface 25 may also consist of a thin metal layer completely covering that surface and produced or applied in a similar way as the rear electrode 27.

Crystal piece 24 with electrodes 26, 27 is mounted within a cylindrical recess 28 of an electrical insulator 29, for instance of glass or ceramic material. Recess 28 is continued by a larger recess 30 into which a metal ring 31 is fitted, e. g. screwed or cemented. Ring 31 is supported in vessel 17 by means of four radial spokes 32 which in this exemplification of the invention are made particularly cast in one piece with the lower part of vessel 17.

The outer contour of insulator 29 may be streamlined and is continued by the smooth outer surface of ring 31 into its opening 33 in front of surface 25 of vibrator 24, leaving a narrow passage 76 between the insulator and the wall of vessel 17. A hole or bore 34 in insulator 29 is passed by a conductive bolt or rod 35 whose lower end projects into recess 28 to form a rivet 36 which holds in place a flat spring 37. This spring comprises in this example four springy arms which rest upon electrode 27 and press piece 24 against the inwardly projecting rim of ring 31. The upper end 38 of rod 35 is screw-threaded and projects outside the top of insulator 29 and recess 39 in it. Two nuts 40, 41 are screwed upon the screw-threaded end 38. Nut 40 engages recess 39 and holds rod 35 and spring 37 in place relative to insulator 29. A conductor 42 is clamped between nuts 40 and 41 and leads to a rod 43 passing an insulator 44, for instance of glass or ceramic material. This insulator comprises a cylindrical portion passed through a hole 45 in the wall of vessel 17; an insulating ring 46 is fitted upon the projecting inner end of that cylindrical portion and held in place by nut 47 screwed upon the inner end of rod 43. The end of lead 42 is conductively connected with rod 43. Nuts 48, 49 are screwed upon the outer end of rod 43 and a terminal 50 is clamped between them. A vacuum sealing compound may be suitably applied in all the gaps between insulating ring 46, insulator 44, wall of vessel 17, rod 43, and nuts 47 and 48.

A conical hood 51 is slipped over and fastened at 53 to the top of insulator 29 and covers the projecting end 38 of rod 35, and the nuts thereon. Thereby the streamlined shape of the vibrator unit is completed and back-reflection of gas molecules toward jar 10 is prevented. The hood may consist of metal or insulating material; in the former case, lead 42 is to be insulated from the hood. Hood 51 is provided with a few small holes (not shown) through which its interior communicates with the surrounding space. Hood 51 can be dispensed with if the end 38 and nuts 40, 41 are fitted into the streamlined contour.

A set of baffles 54 can be arranged above hood 51 as shown more in detail in Figs. 5 and 6; they also serve to prevent back reflection of gas molecules into jar 10.

Any type of generator of recurrent electric impulses or oscillations can be used for exciting the mechanical resonance vibrations of piece 24. Fig. 1 exemplifies the diagram of a Hartley circuit. It comprises in its most simple form and essentially a triode 55 with cathode 56, grid 57 and plate (anode) 58. 59 is a (regulable) source of current for heating cathode 56; 60 a (regulable) source of plate current; 61 a make-and-break switch for starting and interrupting the oscillations; 62 a resistance in the heating circuit of the cathode from which, through leak resistance 63 and adjustable tap 64, a desired bias of grid 57 can be derived; 65 is a block condenser; 66 a self-induction coil and 67 an adjustable condenser, and together they form an adjustable oscillation circuit which determines the frequency and maintains the generation of the oscillations; 68 is an (adjustable) tap for connecting a desired point of coil 66 with the positive terminal of source 60. One end of coil 66 and condenser 67 is connected by conductor 69 with terminal 50, while the opposite end of coil 66 and condenser 67 is connected by conductor 70 with terminal 80 clamped between nut 74 and flange 72. Thus the oscillating voltage generated is applied through conductor 69, terminal 50, rod 49, lead 42, rod 35 and spring 37 to electrode 27, and through conductor 70, terminal 80, vessel 17, spokes 32, ring 31 to the other electrode 26. If anode 58 is to be grounded, conductor 69 will be connected with terminal 80 and vessel 17, and conductor 70 with terminal 50. However this connection be, by adjusting condenser 67, the frequency generated can be varied; by adjusting tap 64 and/or tap 68 the oscillation energy generated and thereby the mechanical vibration energy of piece 24 can be varied. Other means and arrangements for generating supersonic oscillations of desired high frequency and energy can be used instead of the ones illustrated.

In the example shown in Figs. 1 and 2, vessel 17 is sub-divided into an upper and lower portion which are connected by means of flanges 71, 72 and bolts 73 provided with nuts 74. A vacuum sealing compound 75 may be provided between the contacting flanges 71, 72. This sub-division permits convenient mounting of the vibrator unit and its supports within vessel 17, and replacing or exchanging of the former for repair or desired change e. g. of frequency and/or exposed active surface area.

In operation, after bell-jar 10 has been airtightly positioned upon pump plate 11 and valve 14 closed, the backing pump 21 is started by switching in motor 22, and gradually rarefies the gas (air) enclosed in the first or upper confined space comprised of the interior of jar 10, pipe 13 and space 78 within vessel 17 back of insulator 29 and the vibrator unit, as well as in the second or lower confined space 77 within vessel 17 in front of the freely exposed surface 25 of vibrator 24; the first named confined space communicates through passage or gap 76 with the second confined space and the latter through duct 20 with the suction or intake side of pump 21.

After the gas has been rarefied in all the communicating confined spaces named almost to the limit of low pressure attainable by the backing pump, e. g. 10^{-1} to 10^{-2} millimeters mercury column, switch 61 is closed and thereby vibrator 24 and its surface 25 excited to supersonic vibrations of adjusted energy. At the low pressure produced by pump 21, the gas (air in this example) is rarefied to an extent that the average path of free flight of its molecules, i. e. until they collide with one another, or their "mean free path" is in the order of or exceeds the dimensions of passage 76.

It will be seen from Figs. 1 and 2 that vibrator 24 is completely screened or covered against the first confined space as defined above, particularly space 78, and also against passage 76 by insulator 29 and ring 31. Its surface 25 is solely exposed toward the second confined space 77. The direction of the supersonic vibrations of surface 25 is essentially perpendicular to it, and their effective outward stroke is directed toward space 77 and away from passage 76.

If gas molecules impinge upon the vehemently vibrating surfaces 25, the impact of the latter imparts to them a velocity component in the direction of those vibrations, viz. toward space 77 and away from passage 76. These gas molecules are thereby projected into space 77 in the direction of arrows 75 and, since surface 25 vibrates with high velocity and acceleration at supersonic high frequency and it impacts upon impinging gas molecules recur extremely fast, the number of projected gas molecules will be considerable and result in instantaneous, at least local reduction of gas pressure in front of surface 25 and sufficiently close to the discharge end of passage 76 into space 77, to cause diffusion of gas molecules from the first confined space, including space 78, through passage 76 in the direction of arrows 79 toward the front of vibrator 24. Many of the thus diffused gas molecules impinge upon surface 25 and are projected into the second confined space 77 wherefrom they are removed by backing pump 21. Some diffused gas molecules will hit the wall of vessel 17 and be reflected toward surface 25 which throws them into space 77 wherefrom they are removed by pump 21. Only a few diffused gas molecules will return through passage 76 into space 78. Thus the ratio of returning or re-diffusing gas molecules to those effectively removed from space 77 will be very small, particularly if the passage space or area 76 is sufficiently small compared with the effective area of surface 25.

The concurrent phenomena of gas removal just described recur in the frequency of the vibrating surface 25. By proper choice and adjustment of that supersonic frequency and its amplitude, depending inter alia on the kind of gas or vapor undergoing rarefaction, the dimensions of the spaces and the degree of high vacuum to be produced, optimum effects can be attained and the speed of evacuation controlled. The frequency can be varied stepwise by changing the frequency of the oscillation generator from a value corresponding to the fundamental mechanical resonance frequency of the vibrator 24 to any odd (higher) harmonic thereof, e. g. by adjusting condenser 67. The desired amplitude of the mechanical vibrations can be obtained by adjusting positions of tap 64 on resistor 62.

If it were possible to direct and project all the molecules impinging upon surface 25 into the backing pump, no back-diffusion could occur through passage 76, and an almost complete vacuum could be attained. In practice, the back-diffusion and the low pressure limit of the backing pump also limit the degree of highest vacuum attainable in the first confined space including bell-jar 10 by means of a single vibrator pump stage. If higher or highest vacua and/or pumping speeds are desired, two or more vibrator units can be arranged in series. Fig. 3 exemplifies the arrangement in series of two such vibrator units.

Insulator 90 is cone-shaped with its point

within space 78 of vessel 82, and is provided with a lateral bore 91 through which a lead 92 is passed the end of which contacts spring 37 and is riveted with it to bolt 93 positioned within an axial bore 94 of insulator 90. Lead 92 projects air-tightly through an insulator 94 which is air-tightly sealed by means of a vacuum sealing compound 95 into an opening 96 of vessel 82. The outer end of lead 92 is screw-threaded and two nuts 97 and 98 screwed upon it between which terminal 50 is clamped.

Piezo-electric vibrator 24 is cut and shaped in the same manner as described with reference to Figs. 1, 2 and provided with electrodes 27, 26 and supported by the projecting rim of ring 31.

The tapered upper end 81 of vessel 82 fits into the lower end 15 of pipe 13 connected e. g. with a pump plate in the manner shown in Fig. 1. The lower part of vessel 82 expands and ends in flange 83. The upper part 89 of vessel 84 is cup-shaped and ends in flange 85 which is air-tightly connected with flange 83 by means of an interposed vacuum sealing compound 88 and bolts 86 with nuts 87 tightened thereon. In similar manner the lower portion of vessel 84 is expanded and ends in flange 100, while the upper cup-shaped end 101 of the next following vessel 99 ends in flange 102, which is air-tightly connected with flange 100 in a manner similar to the one explained with respect to flanges 83, 85. The adjacent and connecting portions of vessels 82, 84 and 84, 99 are obviously identical and therefore the same reference numbers are used henceforth for identical parts of and in them; only those within vessels 82, 84 shall be described more in detail.

The lower portion of vessel 82 and the cup-shaped upper portion 89 of vessel 84 are shaped so as to confine, together with insulator 90 and its supporting ring 31, a narrow passage 76. In particular, cup-like portion 89 is continued to form an edge 103 of a diameter essentially the same or slightly larger than the innermost diameter of opening 33, i. e. the diameter of the effective vibrating surface. Apart from this, the shape and assembly of ring 31 with inwardly projecting rim, ring-shaped electrode 26, cylindrical piezo-electric crystal piece 24, electrode 27, spokes 32 and spring 37 in the recesses 28 and 30 of insulator 90, are essentially the same as described hereinbefore with reference to Figs. 1 and 2. Spring 37 and lead 92 are threaded and riveted upon pin 93 positioned within a recess of the insulator. Lead 92 extends laterally through a narrow passage 91 in insulator 90. Lead 92 continues through another insulator 94, preferably of glass or ceramic material which is fitted into an opening 96 of vessel 82 and sealed therein by a suitable vacuum sealing compound 95. Lead 92 is also sealed by such a compound into insulator 94, and onto its outwardly projecting screw threaded end nuts 97, 98 are tightened, clamping between them terminal 50.

The top of insulator 90 is cone-shaped and pointed, so as to permit gas molecules to fly in the direction of arrows 104 to passage 76 and to substantially prevent their reflection back towards pipe 13.

Passage 76 is continued around the lower surface of ring 31 and ends with edge 103 in front of the piezo-electric vibrator 24. Hence the gas molecules diffusing in the direction of arrows 104 are guided in the direction of arrows 105 almost completely to the front of vibrator 24 and its vibrating surface 25, impinge upon the latter and are accelerated in the direction of arrows 106 toward insulator **90'** below. Deflection of gas molecules toward and their diffusion back through passage **76** into space **78** back of insulator **90**, is thereby prevented to a larger extent than by the structure shown in Fig. 1; passage **76** is considerably longer and the separation between the incoming and projected gas molecules is improved.

The terminals **50** of the vibrator elements of both stages are assumed to be connected with one terminal of an electrical oscillation generator, while the vessels **99** and **84** and thereby the rings **31** and electrodes **26** in contact therewith are connected by terminal **80** to the other terminal of the generator.

In operation, and after the pre-vacuum has been established in the manner described with reference to Fig. 1, the vibrator elements **24** are actuated by switching in the oscillation generator. It is assumed in this exemplification of the invention that the piezo-electric elements are identical as to shape and mass and consequently excitable to the same resonance frequency which is either the fundamental or a harmonic thereof. Though the supersonic or high frequency of the vibrators is thus the same, the energy of their vibrations may be the same or different, and in the latter event, e. g. the vibrating energy of the lower vibrator larger than that of the upper one. This can be obtained by arranging in conductor **107** an adjustable resistor **108**. Inversely, the upper vibrator may be more strongly excited by corresponding control means. The vibrators can also be excited individually and independently by separate high frequency generators. The sizes or areas of the effective vibrating surfaces **25** may be identical or different.

It will be appreciated that to the gas molecules impinging upon the vibrator surface **25** of the upper vibrator element will be imparted a velocity component directed toward the lower insulator **90'**, across and away from the discharge end (gap) of passage **76** close to surface **25**. Thereby the space in front of vibrating surface **25** is depleted of gas molecules and a suction effect instantaneously produced. The gas molecules projected from vibrating surface **25** also fly across and away from the adjacent discharge end of passage **76** and are apt to produce a kind of ejector effect aided by the particular shape of the discharge end of passage **76** as shown. In any event, diffusion of gas molecules from space **78** through passage **76** into space **77** results, and only a very small fraction of the gas so diffused will revert or diffuse back through passage **76** into space **78**.

As a result, the amount of gas molecules in space **78** and thereby the pressure therein are reduced.

The effect of vibrating surface **25'** of the other, lower vibrator **24'** is essentially the same as just described with reference to the upper vibrator **24**, and will result in the diffusion of gas molecules projected in the direction of arrows **106** within space **77** through passage **76'** in the direction of arrows **109** into space **111**. The gas molecules in the latter space are acted upon and projected by vibrating surface **25'** in the direction of arrows **110**. The gas molecules entering space **111** are finally removed by the backing pump **21** connected with this space through intake **20**.

Assuming that the backing pump is capable of producing a vacuum of 0.1 mm. mercury column, and assuming further that each vibrator stage of the pump can produce and maintain a ratio of pressures in the spaces in front and in the back of the vibrator element or unit, equalling 1000, then a pressure of 10^{-4} mm. mercury will be obtained in space **77** and a pressure of 10^{-7} mm. mercury in space **78** which is a high vacuum sufficient for most applications.

In Fig. 4 a multi-stage pump is exemplified according to the invention. Similar parts used as in Fig. 3 are identified by identical reference numbers. The uppermost or first confined space **78** is connected with a manifold **113**. Bulbs (shown in dotted lines) to be evacuated are connected with the outlets **114**. The bulbs may be for incandescent lamps, electronic tubes, cathode ray tubes, etc. They are melted or sealed off after evacuation in a well-known manner.

In this exemplification of the invention, metal vessels **82**, **115**, **84** are connected through ground with one oscillating potential of an oscillation generator, and through rings **31** and preferably ring-shaped electrodes with each vibrator (piezo-electric element) **24**, **116**, **24'**. The other electrodes **27** on each of the vibrator elements are individually connected through leads **92**, **117**, **118** with terminals **50**, **119**, **120**, and each terminal is individually connected through conductors **121**, **122**, **123** with equal or different potentials of the oscillation generator. These different potentials may be derived either from a single oscillatory circuit by tapping therefrom different voltages, or from different circuits which may also be tuned to different frequencies. Thereby the vibrator elements can be excited with different energies and/or to different supersonic frequencies. When different frequencies are applied to the vibrator elements, their thicknesses must be different in order to respond in resonance to those exciting frequencies; if the thicknesses are identical, higher harmonics can be used for excitation.

It will be appreciated that in the lowest or last confined space **124** the highest of the low pressures is produced and maintained by means of an auxiliary or backing pump. The low pressures in the spaces **125**, **126** and **78** will decrease in the order named so as to produce the lowest pressure or the highest vacuum in space **78** communicating with the interior of manifold **113** and the containers (bulbs) communicating therewith.

It is to be understood that by increasing the number of the vibrator pump stages, the ultimate vacuum attained in space **78** can be increased and, e. g. with three such stages, vacua of 10^{-8} mm. mercury column, or less, attained within a short period of time.

It should be understood that the invention is not limited in any way to the exemplifications shown or any theory propounded herein, but is to be derived in its broadest aspects from the appended claims. Various changes can be made within that scope. Thus, instead of piezo-electric elements exemplified herein in their most simple form, piezo-electric vibrator units can be used comprised of one or more properly cut pieces of piezo-electric material (quartz) and cemented upon or between plates of metal (particularly steel) one of which forms the exposed surface (**25**). Reference is made in this respect to the description and illustrations in my copending application Ser. No. 500,242. Instead of the use of piezo-electric oscillators to form the vibrator unit or part of it, magneto-striction oscillators can be used and in particular a vibrator as described and illustrated in my said copending application, Fig. 7. There is also the possibility of using the vibrating surface of a membrane, partly or entirely of magnetic material, as described and illustrated in my said copending application with reference to Fig. 3 thereof. Instead of metal, such as iron or steel, as shown for the walls of the vessels 17, 81, 82, 84, 115, etc., glass, ceramic and other suitable materials can be used.

What I claim is:

1. In a method of rarefying gas in a first confined space communicating with a second confined space, the steps of producing and maintaining in the gas in said second space a moderately reduced pressure, producing energy vibrations at supersonic high frequency, and applying the vibrational energy in a mean direction away from said first space to gas molecules in said second space to impart to said gas molecules velocity components in said direction away from said first space and cause diffusion of gas molecules from said first into said second space resulting in rarefaction of the gas in said first space.

2. In a method of rarefying gas in a first confined space communicating through a narrow passage with a second confined space, the steps of producing and maintaining in the gas in said second space a moderately reduced pressure of a value at which the mean free path of the gas molecules exceeds the dimensions of said passage, producing energy vibrations at supersonic high frequency, and applying the vibrational energy in a mean direction away from said first space to gas molecules in said second space to impart velocity components to said gas molecules essentially in said direction and promote diffusion of gas molecules through said passage from said first into said second space resulting in rarefaction of the gas in said first space.

3. In apparatus for reducing the pressure of gas in a first confined space communicating through a narrow passage with a second confined space, means exemplified by an auxiliary pump for maintaining a moderately low pressure in said second space, an electrically excitable mechanical vibrator in said second space having a surface element exposed towards said second space and arranged close to the discharge end of said passage, and means for electrically exciting said vibrator and thereby its exposed surface element to vibrations of supersonic frequency in a direction essentially away from said discharge end and perpendicular to said surface element.

4. In a method of reducing the pressure in the gas contained in a series-arrangement of at least three confined spaces including a first and a last space and communicating through narrow passages arranged between each adjacent pair of them, in the first of which the lowest pressure is to be produced, the steps of producing and maintaining in the gas in the last of said spaces a pressure at a level at which the mean free path of the gas molecules exceeds the dimensions of said passages, producing energy vibrations at supersonic high frequency in said second to last spaces and in a direction away from an adjacent passage of lower order number, and applying the vibrational energy to gas molecules in each of said second to last spaces and close to the discharge end of a passage to impart velocity components to gas molecules in each of said second to last spaces in said direction and promote diffusion of gas molecules through each of said passages from a connected space of lower order number into that of next higher order number, resulting in reduction of pressure in the gas in each space from which it diffuses and lowest pressure in the gas in the first space.

5. In a method of rarefying gas in a first confined space communicating through a narrow passage with a second confined space, the steps of prerarefying the gas in said second space to a degree at which the mean free path of the gas molecules exceeds the dimensions of said passage, producing energy vibrations at supersonic high frequency close to the discharge end of said passage and in a direction away from said discharge end, and applying the vibrational energy to gas molecules in said second space to impart velocity components in said direction to said gas molecules in said second space and locally deplete of gas molecules a portion of said second space where said vibrations are produced close to said discharge end, resulting in diffusion of gas molecules through said passage from said first into said second space toward its depleted portion and increased rarefaction of the gas in said first space.

6. In a method of producing a difference of high vacuum pressure in gas confined in a first and a second space which communicate through a narrow passage, the steps of prerarefying the gas in said communicating spaces to a degree at which the mean free path of the gas molecules exceeds the dimensions of said passage, producing energy vibrations at supersonic high frequency and in a direction away from said passage and first space, and applying the vibrational energy to gas molecules in said second space to impart velocity components to said acted upon gas molecules in said direction away from said passage resulting in promotion of diffusion of gas molecules through said passage from said first into said second space and increased rarefaction of the gas in said first space.

7. In apparatus for producing a high vacuum in a container by means of a molecular high vacuum pump and an auxiliary vacuum pump, a high vacuum pump essentially comprising a first confined space communicating through a narrow passage with a second confined space and said auxiliary pump, the dimensions of said passage smaller than the mean free path of the gas molecules at the reduced pressure to be produced by said auxiliary pump, a piezo-electric vibrator unit arranged in said second space close to the discharge end of said passage, said unit provided with a surface element exposed towards said second space and capable of vibrating essentially in a direction perpendicular to its exposed surface and away from said passage and first space, and electrical means for applying oscillatory electric energy of selected supersonic frequency to said vibrator unit for exciting it and thereby its surface element to mechanical vibrations of said frequency or a harmonic thereof and essentially in said direction.

8. An apparatus for producing a high vacuum in a container, essentially comprising a vessel the interior of which is subdivided in a first and second space communicating through a narrow gap, means for connecting said first space of the vessel with a container to be evacuated, means for connecting said second space of the vessel with a pre-vacuum pump, a mechanical vibrator capable of being electrically excited to vibrations of selected supersonic frequency mounted within said vessel and provided with an exposed surface element arranged close to said gap and facing said second space, said surface element capable of vibrating in a direction es-

sentially perpendicular to it, and electrically conductive means for connecting said vibrator with a source of oscillatory electrical energy of said selected supersonic frequency.

9. An apparatus for producing a high vacuum in a gas within confined space, including a vessel the interior of which is subdivided in a first and second space communicating through a narrow gap, means for connecting said first space with the confined space to be evacuated, means for connecting said second space of the vessel with a pre-vacuum pump, the dimensions of said gap being smaller than the mean free path of the molecules of said gas at pre-vacuum pressure to be produced by said pump, a piezo-electric vibrator element capable of being excited to mechanical vibrations of selected high frequency within said vessel, means as exemplified by an electrical insulator supporting and covering said vibrator element but leaving exposed a surface element of it, said surface element close to said gap and facing said second space, said vibrator element capable of vibrating in a direction essentially perpendicular to said surface, and electricallly conductive means for connecting said vibrator element with a source of electrical oscillatory energy of said selected high frequency.

10. An apparatus for producing a high vacuum in a gas in within confined space, including an elongated vessel, at least one piezo-electric vibrator element capable of being excited to mechanical vibrations of selected supersonic frequency, means as exemplified by an electrical insulator for supporting within said vessel and covering said vibrator element but leaving exposed a surface element of it, said vibrator element and supporting means arranged within said vessel so as to leave a narrow gap between them and said vessel, said surface element capable of vibrations in a direction essentially perpendicular to it, electrically conductive means for connecting said vibrator element with a source of electric oscillatory energy of said selected supersonic frequency, means in the back of said supporting means for connecting in open communication said vessel with a container to be evacuated, and means in front of said vibrator element and its exposed surface element for connecting in open communication said vessel with another pump space.

11. For use with a container of gas to be rarefied and a pre-vacuum pump, an elongated vessel open at opposite ends, the first of said ends to be connected with the container and the second of said ends to be connected with the pre-vacuum pump, said vessel comprising at least two spaces communicating through a narrow passage, the first of said spaces communicating with said first end and the second of said spaces communicating with said second end, a mechanical vibrator capable of being electrically excited to vibrations of supersonic high frequency mounted within said vessel between said spaces and surrounded by said passage, said vibrator having a surface element arranged close to said passage and facing and exposed to said second space, said surface element capable of vibrating in a direction essentially perpendicular to it, and electrically conductive means for connecting said vibrator with a source of oscillatory electrical energy for exciting said vibrator.

12. The combination including a container for gas to be rarefied, a pre-vacuum pump, and a vessel, said vessel at a first place communicating with said container and at another second place communicating with said vacuum pump, said vessel comprising at least two spaces communicating through a narrow passage, the first of said spaces communicating with said first place and the second of said spaces communicating with said second place, a mechanical vibrator capable of being electrically excited to vibrations of supersonic high frequency mounted within said vessel and provided with an exposed surface element arranged close to said passage and facing said second space, said surface element capable of vibrating in a direction essentially perpendicular to it and away from said passage and first space, and electrically conductive means for connecting said vibrator with a source of oscillatory electrical energy for exciting said vibrations.

13. The combination including a container for gas to be rarefied, a pre-vacuum pump, a source of oscillatory electrical energy, and a vessel, said vessel at a first place communicating with said container and at another, second place communicating with said pre-vacuum pump, said vessel comprising at least two spaces communicating through a narrow passage, the first of said spaces communicating with said first place and the second of said spaces communicating with said second place, a mechanical vibrator capable of being electrically excited to vibrations of supersonic high frequency mounted within said vessel and provided with an exposed surface element arranged close to said passage and facing said second space, said surface element capable of vibrating in a direction essentially perpendicular to it and away from said passage and first space, and electrically conductive means for connecting said vibrator with said source of oscillatory electrical energy, said ocillatory energy adapted to excite said vibrations.

14. In a method of rarefying gas in a first confined space communicating with a second confined space, the steps of producing and maintaining in the gas in the second space a maximum pressure of about 10^{-1} millimeters mercury column, producing energy vibrations at a frequency of about 100,000 to 10,000,000 cycles per second in a direction away from said first space, and applying the vibrational energy to gas molecules in said second space to impart velocity components to said molecules in said direction and thereby cause diffusion of gas molecules from said first into said second space, whereby the gas in said first space may be rarefied and its pressure reduced to below about 10^{-4} millimeters mercury column.

ADOLPH H. ROSENTHAL.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,433,258	Buckley	Oct. 24, 1922
1,729,579	Hayes	Sept. 24, 1929
2,312,712	Hartline	Mar. 2, 1943
2,152,241	Coons	Mar. 28, 1939

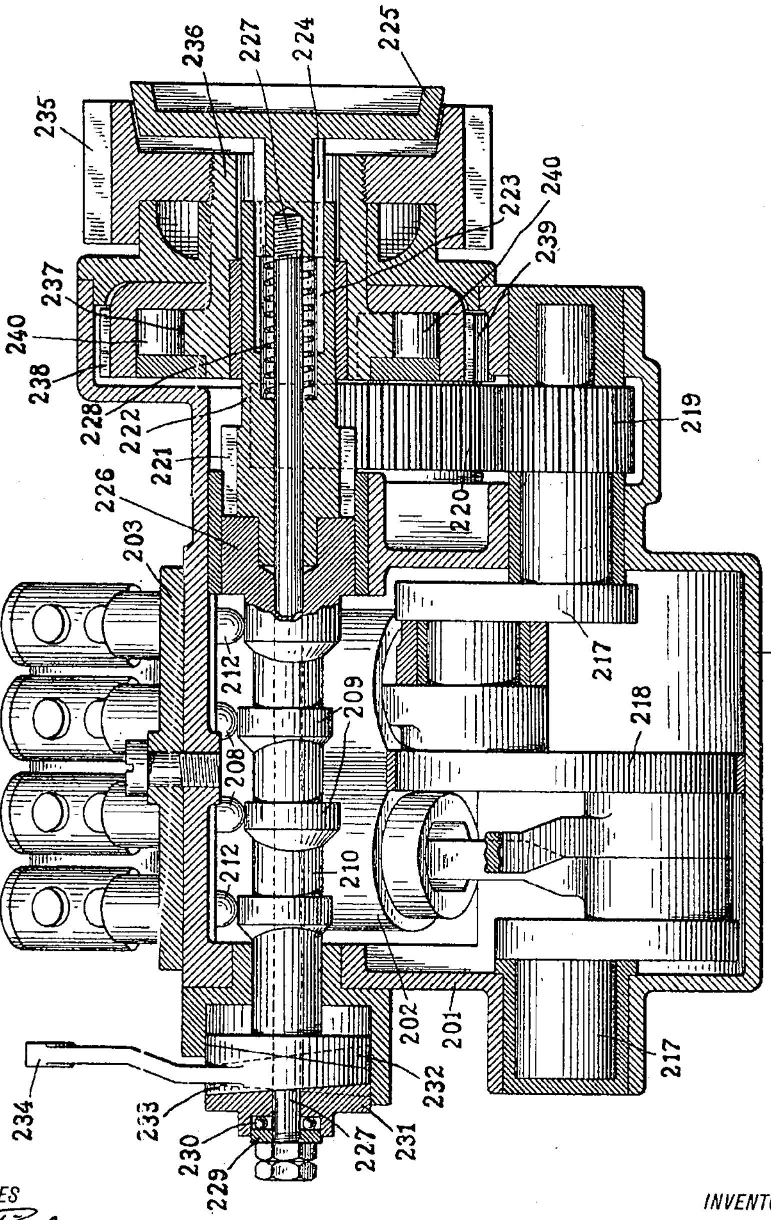
67

W. H. SHIMPF.
MOTOR STARTING DEVICE.
APPLICATION FILED APR. 15, 1914.

1,144,437.

Patented June 29, 1915.
3 SHEETS—SHEET 1.

Fig-1-



WITNESSES

Kate Brenner

INVENTOR
Walter H. Shimpf,
BY
ATTORNEY

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

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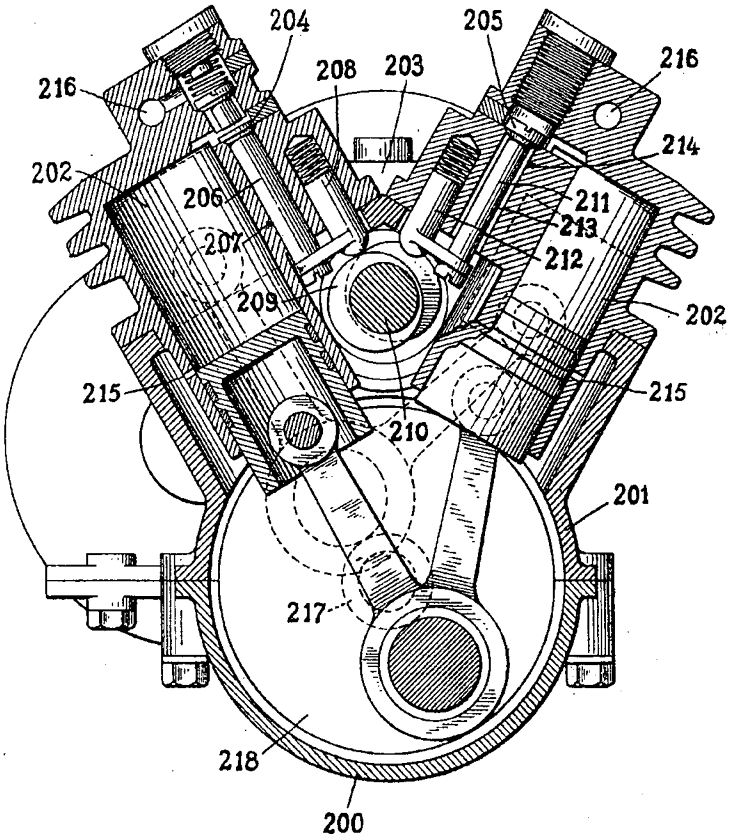
3 SHEETS—SHEET 2.

Fig. 2.



WITNESSES
J Clyde Ripley.
Kate Brenner

INVENTOR
Walter H. Shimpf,
BY W. K. Barker
ATTORNEY

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

W. H. SHIMPF.
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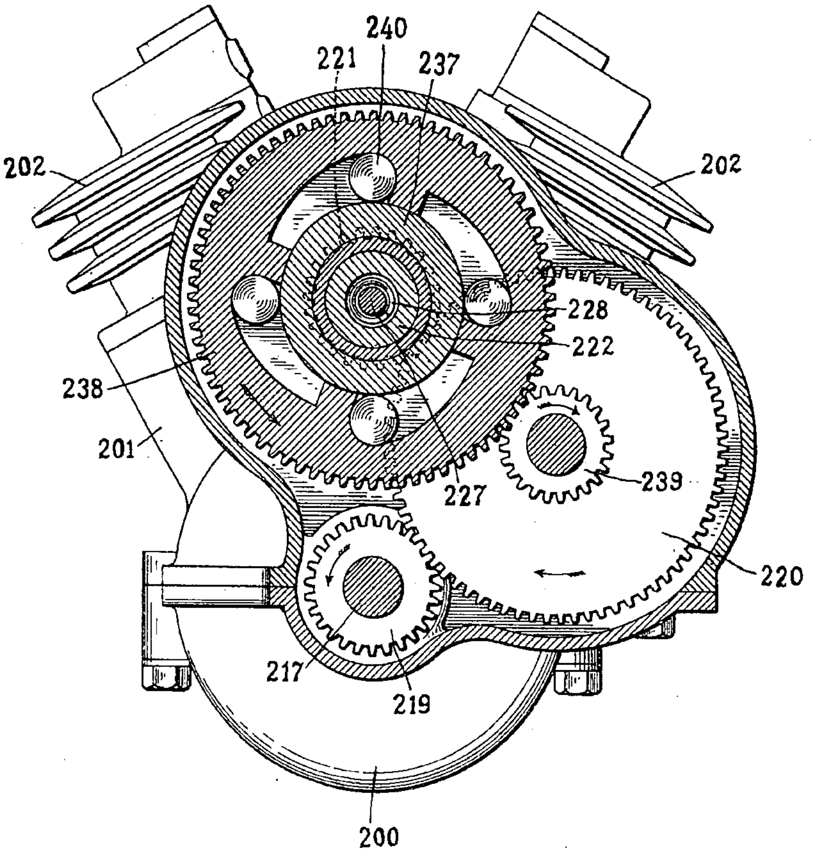
3 SHEETS—SHEET 3.

Fig. 3.



WITNESSES
J. Clyde Ripley.
Kate Brenner

INVENTOR
Walter H. Shimpf,
BY
ATTORNEY

THE NORRIS PETERS CO., PHOTO LITHO., WASHINGTON, D. C.

UNITED STATES PATENT OFFICE.

WALTER H. SHIMPF, OF BOSTON, MASSACHUSETTS, ASSIGNOR TO SHIMPF STARTER COMPANY, OF BOSTON, MASSACHUSETTS, A CORPORATION OF MASSACHUSETTS.

MOTOR-STARTING DEVICE.

1,144,437. Specification of Letters Patent. **Patented June 29, 1915.**

Application filed April 15, 1914. Serial No. 831,926.

To all whom it may concern:

Be it known that I, WALTER H. SHIMPF, a citizen of the United States, and a resident of Boston, in the county of Suffolk and State of Massachusetts, have invented certain new and useful Improvements in Motor-Starting Devices, of which the following is a full, clear, and exact description, whereby any one skilled in the art may make and use the same.

The invention, as indicated by the title, relates to a device to be used as a starter for motors and the like. It is in effect a prime mover when it operates to act as a starter and is a compressor for storing energy in the form of compressed air when it is driven by the motor or engine in conjunction with which it is used. Obviously, the device is not limited to engine starting purposes, but the mechanism illustrated and described is particularly designed for such purposes.

In a co-pending application entitled "Starting motor and compressor", Serial No. 729,450, filed Nov. 4, 1912, there is illustrated and described a device of a similar character in which the control of the valves for changing the device from a prime mover to a compressor is secured to a shifting cam shaft which is common to all of said valves and in order to secure the proper coöperation between the driving mechanism for the crank shaft and main shaft with reference to the shifting of the cam shaft, independent clutches are employed. This necessitates a separate manipulation for the clutches and for the shifting of the cam shaft with the attendant complications.

In the present invention, the mechanism is much simplified and while all the advantages of a shifting cam shaft are retained, a single operating and controlling mechanism serves to control the cam shaft and the clutch mechanism so that there is a simultaneous coöperative action between all the working parts of the machine. This insures positive and proper operation in function of all the parts in extremely simple and compact form of device.

The objects of the present invention are to provide a shifting cam shaft control for the valves to transform the device from a motor to a compressor or vice versa and a control of the driving mechanism corresponding to the control of the valves through a single controlling mechanism.

Further objects of the invention reside in the details and arrangements as hereinafter more specifically described.

Referring to the drawings: Figure 1 is a longitudinal section through the device. Fig. 2 is a cross-sectional view with parts broken away to better illustrate the construction. Fig. 3 is a cross-sectional view through the transmitting mechanism.

As hereinafter described, the main crank shaft and driving shaft of the device always rotate in the same direction whether the device is acting as a prime mover or as a compressor and there is a difference in speed ratio between the crank shaft and main driving shaft secured through intermediate gearing and clutches which gives a uniform speed of rotation between said shafts when the device operates as a motor and an increased speed ratio upon the crank shaft when the device is being driven from the main shaft as a compressor. Furthermore, the mechanism provides for idle running of the motor parts when the device acts neither as a motor nor compressor.

Referring to the drawings 200 denotes a crank case having an upper section 201 in which the several cylinders 202 are arranged in V form. These cylinders are conveniently held in position by a longitudinal locking bar 203 bolted to the main casing. The removal of this bar permits the removal of the the cylinders, valves and appurtenant parts.

Each cylinder is provided with an inlet and exhaust valve best illustrated in Fig. 2, where the section through one cylinder illustrates the inlet valve 204 and the opposed cylinder shows its exhaust valve 205.

The inlet valve 204 is of the puppet type and is actuated by the valve rod 206 which valve rod serves as a closure for controlling the passage 207 leading into the crank case. The rod 206 is connected with a spring-pressed plug 208 which is in position to be engaged by a cam 209 upon the cam shaft 210.

The exhaust valve 205 has a rod 211 connected with a spring-pressed plunger 212 which is also actuated by a cam upon the cam shaft 210. The cams in either instance are of the eccentric type and there is a cam for each valve rod. The rod 211 of the exhaust valve 205 is grooved as at 213 or is made of lesser diameter than the passage 214 and this provides an initial or auxiliary exhaust by which the pressures in the cylinders may be relieved when the device is operating as a motor. When operating as a compressor the valve 205 remains closed and thereupon the inlet valve 204 operates automatically. Each cylinder has a main exhaust 215 which is effective when the device operates as a motor and serves as an inlet when the device operates as a compressor. These exhaust ports 215 are controlled by the various pistons and open into the crank case.

The inlet valves are all connected with manifold ducts 216 so that as each of the cylinders compresses, it will force the compressed fluid through said manifold and when the device operates as a motor, the compressed air will flow from said manifold into the cylinders as the inlet valves are mechanically opened by the valve rods 206.

The several pistons are suitably connected with a crank shaft 217 which is mounted in suitable bearings in the crank case and has a central disk 218 provided with a bearing in the crank case which insures maintaining the crank shaft in alinement under the heaviest sort of duty. At one end of the crank shaft, there is a pinion 219 which, through a gear 220 drives a pinion 221.

The pinion 221 is secured to a quill 222 provided with grooves 223 which are engaged by keys 224 upon a clutch disk 225. The quill 222 is also secured to and rotates with the hollow shifting cam shaft 226.

A rod 227 extends through the hollow cam shaft and is secured to the hub of the clutch disk 225, a spring 228 normally tending to separate the clutch disk 225 and quill 222.

The outer end of the rod 227 terminates in a thrust plate 229 having an anti-friction bearing 230 in a beveled stationary head plate 231. Opposed to the plate 231 is a similar beveled plate 232 which bears against the end of the cam shaft 226 and between the two plates 231 and 232 is a rotatable wedging disk 233 which is actuated in any suitable manner through a lever 234. This lever may obviously be manually operated or it may be connected with any suitably automatic device such, for instance, as an air piston.

From the above, it will be apparent that the pinion 219 will always drive the cam shaft 226 when the device is operating as a motor. The main driving gear 235 is mounted upon a sleeve 236 which rotates with reference to the quill 222 and is provided with a clutch face 237. This clutch face is encircled by a gear 238 mounted to move relatively to the clutch face 237 and meshes with a pinion 239 which is secured to the gear 220. Intermediate the clutch face 237 and the interior of the gear 238 are arranged roller clutch members 240.

When the device is operating as a motor, the clutch 225 is out of engagement with the clutch face 225^a and the eccentrics of the cam shaft are in position to actuate all of the valve rods. The pinion 219 now driving through the gear 220, pinion 239 and gear 238 causes said gear to clutch the sleeve 236 and rotate the main gear 235. When the lever 234 is shifted, the cam shaft is moved and its eccentrics thrown out from under the valve rods and simultaneously, the clutch 225 is engaged with the clutch surface 225^a. Thereupon, the rotation of the gear 235 will release the gear 238 from the clutch surface 237 of the sleeve 236 and the quill 222 will be directly rotated, transmitting motion through the pinion 221 and gear 220 to the pinion 219 of the crank shaft.

The angularity of the plates 231 and 232 is so designed with reference to the intermediate member 233 that a partial rotation of the member 233 will release the clutch 225 without bringing the eccentrics under the valve rods and with the parts in this adjustment, no motion will be transmitted by the gear 235 to the crank shaft, said gear 235 running idle.

From the above, it is apparent that the entire control for throwing the device in operation as a motor, as a compressor or permitting it to run idle, is secured by the manipulation by the actuator for the cam shaft, simultaneously controls the main clutch. This is made possible by the arrangement of gears and automatic clutch.

The exact arrangement of cylinders, pistons and appurtenant parts is, of course, not material and the number and disposition of the cylinders may be modified so long as all of the valves are actuated from a single cam shaft which is arranged to be shifted axially and is controlled simultaneously from the same actuating mechanism with a main clutch.

What I claim as my invention and desire to secure by Letters Patent is:

1. In a motor starting device, a plurality of cylinders, a piston and connecting rod for each cylinder common to a single crank shaft, an inlet and exhaust valve for each cylinder, a shiftable cam shaft gear-connected with said crank shaft and adapted to mechanically actuate all of the valves of the several cylinders and permit automatic operation of the inlet valves, a main driving gear adapted to be driven by the crank shaft and adapted to drive said crank shaft, a clutch for said gear and a single actuating device for operating said clutch and shifting the cam shaft.

2. A motor starting device having a plurality of cylinders, pistons and a single crank shaft common to all of said pistons, a shiftable cam shaft, inlet and exhaust valves for each of said cylinders adapted to be actuated by said shaft when the device operates as a motor and inoperative with reference to all of said valves when the device operates as a compressor, a main driving gear, a main clutch for said gear, driving connections intermediate the crank shaft and said gear controlled by said clutch and an actuating device common to the shifting cam shaft and clutch whereby said shaft and clutch are controlled to vary the operation of the valves and the driving mechanism intermediate the crank shaft and driving gear dependent upon whether the device operates as a motor or as a compressor.

3. In a motor starting device, a cylinder, piston and crank shaft, an inlet and exhaust valve for the cylinder, both mechanically operated when the device operates as a motor, a hollow shifting cam shaft actuating said valves as a motor, a main driving gear having driving connections with the crank shaft, an actuating rod for said gear passing through the crank shaft and a controlling device for shifting the cam shaft and the clutch.

4. In a device of the character described, a plurality of cylinders, each having a piston, a main crank shaft common to all of said pistons, connections intermediate the shaft and pistons, an inlet and exhaust valve for each of said cylinders, a shiftable cam shaft for actuating all of said valves when the device operates as a motor and permitting automatic action of the inlet valves when the device operates as a compressor, a clutch member having an auxiliary movement though keyed to said shifting cam shaft, an actuating rod for said clutch extending through said cam shaft and a controlling device common to the cam shaft and clutch rod for shifting said shaft and controlling said clutch.

5. In a device of the character described, a shifting cam shaft, inlet and exhaust valves controlled by said cam shaft, a main crank shaft gear-connected with the cam shaft, a main driving gear bearing a clutch drum, a gear and roller clutches surrounding said drum, said gear driven by the gears intermediate the cam shaft and crank shaft, a clutch member rotating with the cam shaft, and axially movable with reference thereto, said clutch adapted to engage the main driving gear and a single controlling device common to the shiftable cam shaft and connected with the clutch member for varying the control of the valve and the driving gear connections.

WALTER H. SHIMPF.

Witnesses:
Helen V. McCarthy,
Gertrude H. Taft.

Copies of this patent may be obtained for five cents each, by addressing the "Commissioner of Patents, Washington, D. C."